Lucian Claudiu ANGHEL, PhD
lucian.anghel@facultateademanagement.ro
National University of Political Studies and Public Administration, Romania

Maria-Cristina ZWAK-CANTORIU, PhD Candidate (corresponding author)
maria.cantoriu@fin.ase.ro
Bucharest University of Economic Studies, Romania

Carmen OBREJA, PhD
carmen.obreja@fin.ase.ro
Bucharest University of Economic Studies, Romania

Mohd AFJAL, PhD
afzalmfc@gmail.com
VIT Business School, Vellore Institute of Technology, India

The Impact of "Black Swan" Events on Oil and the European Capital Markets

Abstract. *The price of oil and, indirectly, the performance of the stock indexes were significantly impacted by the evolution of the energy market in the context of the switch to renewable energy sources and the modifications in global energy policy. This paper proposes a comprehensive analysis of several crucial financial field elements, with particular attention to the evolution of stock indices, financial market volatility, and investor response to major events that have recently caused changes in the global economy. Using advanced economic and statistical models, the paper shows the complex relationship between the analysed stock indices, the trends and changes that occurred within them and the relevant influencing factors, such as the price of oil and the Baltic Dry Index.*

The results of the DCC-GARCH models highlight a significant positive correlation between the stock indices of several European countries, underlining the interconnection of these markets in conditions of increased volatility.

Keywords: *correlation, impact of events, oil price fluctuations, DCC-GARCH model, stock indexes, energy market.*

JEL Classification: C01, C12, C32, C38, C53, C55, C58, C61, C81.

1. Introduction

In the current context marked by changes and economic uncertainty, oil price fluctuations are of great importance, both in that they can significantly influence a series of economic indicators whose instability can cause significant financial losses in the economy, as well as for investors. With the rapid development of international relations, in a constantly changing economic context, the interconnection and influences between economic and financial markets highlight the particular

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importance for investors in search of risk hedging strategies and portfolio diversification. With all the rapid changes in the world of oil and its replacement by renewables, oil is an important part of the economy, a necessary commodity for global economies, as well as an important stock market investment tool, and investors want to closely monitor oil prices and the changes that replace it with renewable resources to make informed decisions about their portfolios.

Contemporary events such as medical, geopolitical, or governmental conflicts that have reduced production in the extraction areas have produced strong changes in the price of oil and fluctuations in the prices of stock indices.

The purpose of the paper is to observe the impact of the negative events that have affected the global economy in recent years, to analyse of oil price variations, considering their importance, and to investigate the influence these fluctuations have on the financial markets. The events of recent years make us notice that major changes are observed on the oil market during the COVID-19 pandemic because of the closure of industry and the population during the (lockdown) period, but also of the decrease in mobility, and as such there is a decrease in demand for oil. What made this market unbalanced was the fact that oil production did not decrease at the beginning of the COVID-19 pandemic; on the contrary, it remained the same until the (lockdown) period, a fact that led to an oversupply on the market when many of the oil depots storage became full, and as a result in April 2020 oil prices drop a lot.

The restoration of the oil market and the management of market volatility was done quite quickly with the help of the Organization of Petroleum Exporting Countries (OPEC), which intervened to adjust production. The major changes in the oil market during the COVID-19 pandemic, directly affected the capital market and economic sectors related to the oil industry, and this was best observed when oil prices fell significantly due to the sudden reduction in demand and the stock markets have been negatively affected. The increased volatility in the stock markets because of the uncertainty existing during the COVID-19 pandemic until the discovery of the vaccine, as well as the economic stimulus measures, produced important fluctuations in the prices of the stock indices. Thus, it is found that the increased volatility of oil prices in recent years is due to numerous factors that produced it, including instability in important regions with concentrated oil resources, the COVID-19 pandemic that created production constraints, energy changes, or armed military conflicts. The main objective of the paper is to analyse the recent disturbing episodes, which have affected the price of oil and the return of the stock indices proposed for analysis. The war between Russia and Ukraine affected the oil industry and the energy market in Europe and contributed to the volatility of oil and natural gas, causing price increases on international markets. Russia, one of the world's largest producers and suppliers of oil and natural gas, because of the sanctions and restrictions imposed due to the invasion of Ukraine, has reduced its oil and gas transport to many European countries to the point of cessation. Globally, as Russia has an important influence on energy markets, a disruption of this kind has

significant consequences and can affect national economies, creating pressure on financial stability. At the same time, the armed conflict between Russia and Ukraine has negative consequences on the capital markets as well, and here we can observe the volatility of the financial market, and the damage to investors' confidence due to the geopolitical conflict, led them to look for assets considered safe, such as gold or government bonds, behaviour that influences the direction of stock markets. Events of this kind are called by the analyst Taleb (2008) "black swan" and refer to unpredictable, rare events with significant consequences and massive impact and are considered inevitable and difficult to anticipate. As such, the paper traces the "black swan" periods that had a stronger impact, observing the volatility of oil prices and stock indices during the crisis period of 2008 and especially in the current period when the global economy faced a succession of such events that appeared out of the blue but that changed the economic and financial landscape.

The paper manages to highlight oil volatility and investigate how it influences financial markets using well-known econometric models such as multivariate series analysis and the DCC-GARCH model. The importance of the study, in the current context, consists in highlighting the volatility of oil and stock indices, volatility with a significant impact on the main economic indicators and whose instability can lead to large financial losses for the economy and investors. Therefore, this paper is important for investors in making well-informed investment decisions and anticipating risks. The novelty of the work consists in the interconnection between Brent Oil prices, the Baltic Dry index (BDI) and various European stock market indices such as those on: the Romanian stock market (BET index), the Polish stock market (WIG index), the French stock market (CAC40 index), the German stock market (DAX index), the Austrian stock market (ATX index), the Dutch stock market (AEX index) and the English stock market (FTSE100 index) where it is highlighted how the volatility of the oil market can affect the financial market, when there are impacts of negative events such as "black swan".

The analysis covers approximately 15 years, from January 2008 to November 2023, and the results obtained are fully consistent with previous research and confirm the presence of volatility in these markets. Analysing the intricate relationships between Brent Oil prices, the Baltic Dry Index (BDI) and selected European stock indices, this paper provides a detailed insight into how oil market volatility can affect the performance of financial markets. The results obtained provide investors with a valuable mechanism to better understand the risk associated with the oil market and to identify investment opportunities in a volatile environment and provide important steps in making more informed and accurate investment decisions. By looking at current events and their impact on financial markets, the study provides a comprehensive analysis of trends and influences that can lead to more informed decisions in the future.

To achieve the set objectives, this paper is divided as follows: literature review, methodology, results and discussion, and conclusions.

2. Literature review

The specialised literature highlights the factors and volatility of oil, as well as its impact on the performance of the financial market. Some significant works on the volatility of oil prices in the field are the work of Dvir and Rogoff (2009), which shows both the dynamic behaviour of oil prices and the fact that shocks on the oil market have different effects on the real price of oil not because of supply or demand, but because of the ability (or lack thereof) of key market players to restrict access to supplies. Therefore, effective restrictions on access to excess supply can generate oil price growth, shocks that are persistent, and with increased volatility. In their remarkable study, Fedorova and Saleem (2010) shed light on the complexity of volatility in Central Eastern European markets. In a particularly detailed and meticulous effort, the authors analyse four key European states, and by exploring unidirectional and bidirectional linkages, the study reveals the spread of volatility in these countries. With a multidirectional approach, the researchers investigate the mutual influence between financial markets and currency markets in each country in part, and to examine the transmission of shocks and volatility, the authors use an unrestricted bivariate GARCH-BEKK (1,1) model, thus providing a deep insight into how changes in one domain can affect and shape behaviour in another domain. Through this detailed and rigorous research, Fedorova and Saleem (2010) make significant contributions to understanding the complex interactions between the financial and foreign exchange markets of these countries, thereby providing a solid basis for further analysis and decision-making in the context of market volatility.

Contagion and volatility between crude oil and financial markets is investigated by Chatziantoniou et al. (2021) through a standard vector autoregressive with time-varying parameters (TVP-VAR), and the results of their study suggest that the crude oil market is an important transmission network for volatility shocks.

In their work Abhyankar, Xu and Wang (2013) using a structural vector autoregressive model (SVAR), show the relationship between oil price shocks and the Japanese stock market, and according to the results obtained, it is found that the oil price shocks arising from changes in global aggregate demand are positively correlated with the return of the Japanese stock market, which means that an increase in oil prices is not always bad news for the Japanese stock market, as it reacts negatively to increases in oil prices related to specific oil market demand shocks.

In his study, Abdollah (2023) examines oil price volatility by forecasting it, using information from news and Twitter feeds. This study highlights how oil price fluctuations are heavily influenced by factors such as geopolitical conflicts and natural disasters, which are often widely publicised and extensively discussed in the media. Therefore, this research reveals the complex links between significant real-world events and oil market volatility, making a significant contribution to understanding this phenomenon.

The paper written by Lovcha and Perez-Laborda (2022) investigated oil volatility using a FIVAR model. Research results indicate that oil volatility does not exhibit persistence and is characterised by a combination of short and long memory.

The long-memory component gives the volatility series significant persistence. Related measures have shown that while oil volatilities are significantly correlated, they are much less interconnected than standard VAR models suggest, especially at low frequencies. This research provides a deep insight into the behaviour of oil volatility, making significant contributions to understanding the complexity of this phenomenon in the context of financial markets. Research using short-memory multivariate GARCH models by Marchese, Kyriakou, Tamvakis and Di Iorio (2022) focuses on the fundamental relationship between crude oil prices and refined products. The paper in which they were compared for spot yields, three major oil markets examine the potential benefits of using fractionally integrated multivariate GARCH models from a forecasting and risk management perspective. Results indicate that multivariate models incorporating long memory outperform short-memory benchmarks in forecasting the conditional covariance matrix and associated hazard magnitude. The paper makes an innovative contribution to the analysis of the relationship between crude oil and its refined products, providing refiners, physical oil traders, non-oil traders, and other agents in the energy markets with meaningful information for hedging operations and risk management.

Researchers such as Gong et al. (2020) focused on investigating the asymmetric and non-linear laws between shipping costs and financial markets, studying contagion risk in the context of extreme events, and making a significant contribution by using the switch of a Markov copula (MS) model with three variants. Their study revealed contemporaneous two-way lead-lag relationships between the freight market, as measured by the Baltic Dry Index, and the US and Chinese stock markets. The authors identified that the risk of contagion increases as the volume of shipping between the US and China. These findings highlight the importance of the subtleties and interconnections between the economic and financial sectors, bringing to the fore complicated relationships between the shipping market and stock markets.

In their work, Baumeister and Kilian (2016) bring to the fore the complexity and unpredictability of the oil market and the significant impact it has on economies and financial decisions. It is demonstrated that the magnitude and timing of price shocks depend largely on expectations regarding the evolution of oil prices. Price shocks reside in the fact that they influence the economic decisions of individuals and companies. Higher gasoline prices generate an increase in the price of oil, which reduces the income available for other activities, thus affecting household spending. Another significant impact of oil price shocks is related to expectations regarding the future of oil prices. These expectations are essential in calculating the net present value (NPV) for future investment projects that depend on the price of oil, such as car manufacturers making key decisions about new car models depending on the price of oil, and households deciding what type of car to buy, both of which are influenced by the evolution of oil prices in the future. It is observed that oil price shocks are not only limited to the current value of the price, but rather to how they change the expected course of the price in the future. These complex dynamics underscore the importance of careful analysis of the oil market and how it can affect

economic decisions and investments, thereby providing significant insight for economic and financial actors. Alamgir and Amin (2021) in their study use a Nonlinear Autoregressive Distributed Lag (NARDL) model to investigate the complex relationship between oil prices and the stock market. The results obtained reveal a strong positive relationship between the world oil price and the stock market indices, and, what is more remarkable, the response of the stock market index to positive and negative oil price shocks is asymmetric. The study shows that higher oil prices in the world market have a significant stimulatory effect on the share price. This finding not only highlights the importance of oil prices in the dynamics of financial markets, but also highlights the sensitivity to events and changes in the oil industry. Therefore, this research provides a significant contribution to understanding the subtleties of the relationship between oil prices and the behaviour of stock markets, providing a clear and detailed insight into the complex impact they have on the economy.

Prabheesh, Padhan and Garg (2020) investigated the relationship between oil price returns and stock price returns using the DCC-GARCH model for four major oil importing countries in Asia. Although the authors find that the correlations between the two price returns are small, the values are positive. Therefore, this positive move may reduce opportunities for portfolio diversification as the uncertainty associated with COVID-19 may affect economic performance considering lower oil prices, which act as a signal of future demand contraction and the associated weak economic outlook.

In their study García and Rambaud (2023) reveal an important aspect of international oil markets. These researchers emphasise that the volatility of oil prices is a complex phenomenon, generated by shocks and frictions of demand and supply, a phenomenon that amplifies in periods of international crisis. The methodology of the paper combines the analysis of volatility using the GARCH model with the impulse response method for shocks and with the index approach of spillover by Diebold and Yilmaz (2012), and the results obtained show significant increases in volatility in the months correlated with economic blockages in the US economy and with the identification of the channel of uncertainty as the main factor leading to the spread of volatility, the COVID- 19 pandemic, when price volatility in international oil markets reached unprecedented levels, surpassing even the levels recorded during the financial crisis of 2007-2009. The research makes a significant contribution to understanding the complexity of volatility in oil markets, and clearly shows how factors such as uncertainty and international crises can have a profound and lasting impact on world economies.

3. Methodology

In order to analyse the implications of current events on the price of oil and the performance of the stock exchanges, we took into account oil prices, the Baltic Dry index (BDI), as well as some of the most significant stock market indices, namely: the Bucharest Stock Exchange index (BET), the Warsaw Stock Exchange index (WIG), the Frankfurt Stock Exchange index (DAX), the London Stock Exchange index (FTSE100), the Amsterdam Stock Exchange index (AEX), the Vienna Stock Exchange index (ATX) and the index of the Paris Stock Exchange (CAC 40). The study of the paper begins with the determination of the descriptive statistics, emphasising the most significant descriptive statistics, including the determination of the mean, skewness, kurtosis, and standard deviation.

The emergence and development of GARCH (Generalized Autoregressive Conditional Heteroskedasticity) models was and is an important step in economic research because they manage to capture volatility and heteroskedasticity in financial and economic time series, by allowing the estimation of the conditional variation of the data according to the information available in the past, an important fact in risk assessment.

Engle (1982) first developed the ARCH model, which he then extended so that he reached the GARCH model because this model is much more efficient in the face of the nonlinear conditional variation and the correlation between the residuals of the time series. Bivariate GARCH models (Engle and Sheppard, 2001) are an extension of GARCH models that allow the analysis of volatility and correlation simultaneously between two time series.

The utility of these models lies in their ability to assess the relationships between various financial assets or economic variables, leading to an understanding of how volatility and correlation change over time. According to Brooks (2014), a variety of models can be observed that are part of the GARCH family, among which the GARCH-DCC (Dynamic Conditional Correlation GARCH) model is also mentioned, which was also addressed in this work, due to its properties, which allow the simultaneous modelling of several financial variables and the determination of their dependence.

Thus, GARCH models and bivariate GARCH models have played a significant role in the financial and econometric analysis in this paper, providing useful tools for modelling and predicting volatility and correlations in time series.

As described by Orskaug (2009), the DCC-GARCH model is characterised by the formulas:

$$r_t = \mu_t + a_t \tag{1}$$

$$a_t = H_t^{1/2} z_t \tag{2}$$

$$H_t = D_t R_t D_t \tag{3}$$

where: r_t represents a vector of the returns calculated using the logarithm formula; a_t represents a vector of adjusted returns; μ_t represents a vector of the expected

value of r_t; H_t represents the matrix of conditional variances of a_t; D_t represents the diagonal matrix of the conditional standard deviation of a_t and R_t represents the conditional correlation matrix of a_t.

Engle (2002) and Orskaug (2009) explained that the elements from matrix D_t represents the standard deviation from univariate GARCH models.

$$D_t = \begin{bmatrix} \sqrt{h_{1t}} & 0 & \cdots & 0 \\ 0 & \sqrt{h_{2t}} & \ddots & \vdots \\ \vdots & \ddots & \ddots & 0 \\ 0 & \cdots & 0 & \sqrt{h_{nt}} \end{bmatrix} \tag{4}$$

where:

$$h_{it} = \alpha_{i0} + \sum_{q=1}^{Q_1} \alpha_{iq} a_{i,t-q}^2 + \sum_{p=1}^{P_1} \beta_{ip} h_{i,t-p} \tag{5}$$

R_t represents the correlation matrix of the standardised disturbances ε_t and is characterised by the formula:

$$\varepsilon_t = D_t^{-1} a_t \sim N(0, R_t) \tag{6}$$

The correlation matrix R_t is symmetrical and is characterised by:

$$R_t = \begin{bmatrix} 1 & \rho_{12,t} & \rho_{13,t} & \cdots & \rho_{1n,t} \\ \rho_{12,t} & 1 & \rho_{23,t} & \cdots & \rho_{2n,t} \\ \rho_{13,t} & \rho_{23,t} & 1 & \ddots & \vdots \\ \vdots & \vdots & \ddots & \ddots & \rho_{n-1,n,t} \\ \rho_{1n,t} & \rho_{2n,t} & \cdots & \rho_{n-1,n,t} & 1 \end{bmatrix} \tag{7}$$

The DCC-GARCH model assumes a decomposition of R_t in:

$$R_t = Q_t^{*-1} Q_t Q_t^{*-1} \tag{8}$$

$$Q_t = (1 - a - b)\bar{Q} + a\epsilon_{t-1}\epsilon_{t-1}^T + bQ_{t-1} \tag{9}$$

where: $\bar{Q} = Cov[\epsilon_t \epsilon_t^T] = E[\epsilon_t \epsilon_t^T]$ represents the unconditional covariance matrix of standard errors ϵ_t. $\bar{Q}$ is characterised by the estimate:

$$\bar{Q} = \frac{1}{T} \sum_{t=1}^{T} \epsilon_t \epsilon_t^T \tag{10}$$

The parameters a and b in the equation above are scalars and Q_t^* is a diagonal matrix with the square root of the diagonal elements of Q_t:

$$Q_t^* = \begin{bmatrix} \sqrt{q_{11t}} & 0 & \dots & 0 \\ 0 & \sqrt{q_{22t}} & \ddots & \vdots \\ \vdots & \ddots & \ddots & 0 \\ 0 & \cdots & 0 & \sqrt{q_{nnt}} \end{bmatrix} \quad (11)$$

To estimate the impact of current events on the oil and stock markets, in certain economic sectors, such as the energy sector (oil), and the financial sector (stock exchanges), we've used the data sets of the representative indices of these markets. Thus, in this paper, we've performed an analysis of the impact of current events on the oil and stock markets between the two sectors mentioned above by using data with daily frequency over a period of 15 years (January 2008 – November 2023) based on the closing prices of Brent crude spot oil (the reference index for the price of Brent crude oil, which is listed on the Nasdaq stock exchange, and which is used as a global reference for the price of quality crude oil superior) and Baltic Dry index (the cost of transporting the main raw commodities). From the perspective of the financial sector, we have used as stock market indices some representative indices of some European stock exchanges: BET index (Bucharest Stock Exchange index), WIG (Warsaw Stock Exchange index), CAC40 (Paris Stock Exchange index), FTSE100 (London Stock Exchange), AEX (Amsterdam Stock Exchange), DAX (Frankfurt Stock Exchange index) and ATX (Vienna Stock Exchange) based on which we've calculated the returns using the logarithmic formula. The series of data was collected from the Reuters and Nasdaq financial platforms.

Table 1. Correlation of coefficients between variables

	Brent Oil	**BDI**	**BET**	**WIG**	**CAC40**	**DAX**	**AEX**	**FTSE100**	**ATX**
Brent Oil	1.00								
BDI	0.03	1.00							
BET	-0.26	-0.01	1.00						
WIG	-0.32	0.01	0.61	1.00					
CAC40	0.35	-0.01	-0.61	-0.76	1.00				
DAX	0.33	-0.01	-0.60	-0.76	0.95	1.00			
AEX	-0.37	-0.01	0.62	0.75	-0.95	-0.92	1.00		
FTSE100	-0.42	0.01	0.58	0.72	-0.90	-0.87	0.90	1.00	
ATX	-0.36	0.01	0.65	0.75	-0.86	-0.85	0.85	0.81	1.00

Source: data collected from Yahoo Finance - own processing and calculations.

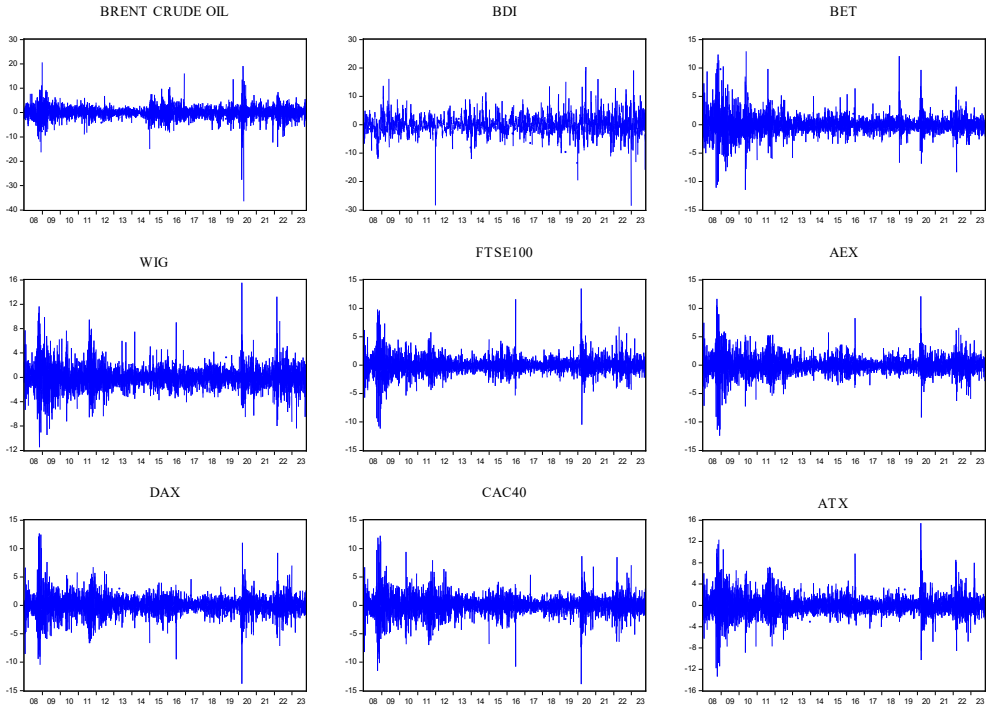

Figure 1. Price evaluation of the four markets as well as of oil and the Baltic Dry index
Source: data collected from Yahoo Finance - own processing and calculations.

In Figure 1, we illustrated the daily evolution of the returns from January 2008 to November 2023. We note that the indicators chosen for analysis are susceptible to volatility, especially during periods with "black swan" events, such as the financial crisis of 2008, the pandemic of COVID-19, or the military conflict between Russia and Ukraine. It is observed that during the outbreak of the crisis in 2008, both Brent Oil, the Baltic Dry index (BDI), and the stock market indices analysed in the paper registered a conglomeration of prominent volatility where the spillover effect can be observed from one stock exchange to another, as well as a sudden drop in prices. The outbreak of the pandemic generated a significant drop in market returns, strongly affecting Brent Oil, the DAX index, and the CAC40 index, a drop that can be classified as the biggest in the last 15 years. The impact of these decreases is mainly due to the major changes in the oil market during the pandemic, due to the closure of the industry and the decrease in mobility, which led to a decrease in the demand for oil, especially for countries like Germany and France, whose industry depends on oil market. According to the graphs in Figure 1, the negative events that took place at the global level (the war between Russia and Ukraine) affected the price of Brent Oil and most stock indices to a lesser extent compared to the COVID-19 pandemic. The most affected index due to the armed conflict was the Baltic Dry (BDI) because of the uncertainty of transports and the change of maritime transport routes.

By applying the correlation coefficient, we were able to have a clearer view of the links between oil and stock markets, as well as those between the Baltic Dry index and oil. According to Table 1, a positive correlation can be observed between the price of oil and the CAC40 and DAX stock indices, which comes as a confirmation of the need to use oil in the industries of these countries and a very weak correlation between Brent Oil and the Baltic Dry index. The most significant negative correlation during the analysed period is found for the FTSE100 with a value of (-0.42). What can be observed is that the correlations between oil, the BDI index, and the stock market indices analysed in this paper are mostly negative correlations and quite weak compared to the correlations between the indices. Thus, it can be said that although there have been "black swan" type events, there is still a significant strong positive or negative correlation between the seven financial markets. A strong negative correlation (-0.92) is evident between the AEX and DAX stock indices, caused by the rule of international companies' decision to list on one of these markets, where transaction costs and transparency play an important role in choosing the stock index.

4. Results and discussion

To analyse the impact of current events on oil price and stock index performance, we will first calculate descriptive statistics and perform stationarity tests for each data series.

Table 2. Results of descriptive statistics and stationarity tests

Variables	Mean	Std.Dev	Skewness	Kurtosis	JB	ADF	PP
Brent Oil	-0.003	2.537	-0.997	23.506	66696.49	0.00	0.00
BDI	-0.047	3.049	-0.033	10.688	9288.916	0.00	0.00
BET	0.006	1.719	0.809	13.410	17439.18	0.00	0.00
WIG	0.007	1.844	0.503	9.119	6042.236	0.00	0.00
FTSE100	0.008	1.469	0.474	13.434	17074.74	0.00	0.00
AEX	-0.001	1.582	0.232	12.069	12827.50	0.00	0.00
DAX	0.008	1.648	-0.137	11.101	10325.13	0.00	0.00
CAC40	-0.002	1.681	-0.200	10.741	9441.381	0.00	0.00
ATX	0.017	1.876	0.411	10.270	8326.767	0.00	0.00

Source: data collected from Yahoo Finance - own processing and calculations.

The results of descriptive statistics and stationarity tests are useful in evaluating and comparing the performances and risks associated with each variable in the context of the analysis.

In terms of performance, the return of BET (Bucharest Stock Exchange Index) shows a positive average return of 0.006, contrary to expectations, given the economic conditions of the last period, as well as WIG (Warsaw Stock Exchange Index) which shows a moderate performance with a yield close to BET. The FTSE100 and DAX stock market indices show the same positive values of 0.008, and the highest positive value is recorded by the ATX index (0.017).

The fact that the returns of the mentioned stock markets had positive values means that, on average, during the analysed period, these financial markets

registered increases. The index of the Paris Stock Exchange (CAC40) recorded a poor performance during the analysed period with a negative average return (-0.002) in the same situation, the Amsterdam AEX index with a value of (-0.001).

In terms of performance, on average, the price of Brent Oil had a negative performance (-0.003) and the Baltic Dry Index (BDI) had a modest performance with the lowest average negative return (-0.047) among the analysed indices. From the results obtained, it can be observed that the movements of the share price have a high volatility with values between 1.469 (FTSE 100) and 1.876 (ATX). Also, from the table above, it can be distinguished that the price of oil shows a low value with high volatility (Std.Dev = 2.5377), and the highest volatility is evident in the Baltic Dry Index (BDI), where there is a fluctuation extremely high price volatility (Std.Dev = 3.0498).

Regarding the measure of the tail of the distribution (i.e., kurtosis), the BET, WIG, CAC40, FTSE100, AEX, DAX and ATX stock indices show excess kurtosis, but within acceptable limits. Brent Oil, however, has a significantly higher value (23.5062), indicating an extreme level of volatility. The obtained results of the descriptive statistics for the analysed period show relatively close and positive performances for most of the stock market indices, except for the CAC40 and AEX indices, which present a negative average return. The volatility of Brent Oil and BDI is higher and shows high volatility of oil prices and the transportation index, and excess kurtosis of oil shows extreme volatility of oil prices.

The results of the stationarity tests show the stability of the time series, and the low probability values in the ADF and PP tests (0.0001) indicate the rejection of the null hypothesis of non-stationarity, a fact which shows that the analysed time series are stationary. These results indicate that the data is constant over time and can be used in analysis models.

Table 3. DCC-GARCH Results

DCC-GARCH model								
Param.	**Variab.**	**Coeff.**	**Variab.**	**Coeff.**	**Variab.**	**Coeff.**	**Variab.**	**Coeff.**
Ω	Brent Oil	0.0668 (0.0046)	BDI	0.6361 (0.1227)	BET	0.0409 (0.0123)	WIG	0.0304 (0.0060)
α_1		0.1026 (0.0000)		0.2593 (0.0001)		0.1108 (0.0000)		0.0693 (0.0000)
β_1		0.8935 (0.0000)		0.6666 (0.0000)		0.8762 (0.0000)		0.9225 (0.0000)
Ω	FTSE100	0.0230 (0.0499)	AEX	0.0228 (0.0059)	DAX	0.0305 (0.005)	CAC40	0.0374 (0.0020)
α_1		0.0898 (0.0001)		0.0949 (0.0000)		0.0854 (0.0000)		0.1143 (0.0000)
β_1		0.8999 (0.0000)		0.8971 (0.0000)		0.9041 (0.0000)		0.8766 (0.0000)
Ω	ATX	0.0423 (0.0010)	DCC	Coef.		Prob	Log-likelihood	
α_1		0.0962 (0.0000)	α	0.0147		0.0000		
β_1		0.8917 (0.0000)	β	0.9691		0.0000	-45356.54	

Source: data collected from Yahoo Finance - own processing and calculations.

The DCC-GARCH model is a complex model, being an extension of the GARCH models. From the perspective of the constant variant (Ω) it can be observed that for most of the variables used it registers positive and statistically significant values, registering a probability lower than 0. The fact that this parameter is positive suggests that between the time series there is a tendency that regardless of the information provided by the market and the price movements, constant positive correlations are maintained between the analysed time series.

The parameters α_1 and β_1 (parameters of the GARCH model) are significant from a statistical point of view, the sum of their coefficients being subunit, which denotes that they satisfy the condition of the GARCH model. If the α_1 coefficient is positive and significant from the statistical point of view, we can say that the recent events (such as the pandemic, the geopolitical conflicts, or crises) have a significant impact over the immediate volatility. Also, from the point of view of β_1, it can be observed a strong GARCH effect, which means a persistence in the level of volatility that leads to the conclusion that past volatility affects present volatility. Among the variables analysed, the closest value to 1 from the sum of coefficients α_1 and β_1 is found in the case of the WIG stock market index (0.9918), AEX stock market index (0.992) and the Brent crude oil (0.9961), which denotes a persistence of very high volatility.

In a DCC-GARCH model, the parameters $dcc\alpha$ and $dcc\beta$ are the most important coefficients, because they can measure the degree of interdependence between the analysed time series and the conditional time variation of the covariance between them.

The $dcc\alpha$ parameter measures the impact produced by the extreme events of the past on the current volatility of the covariance between the series, and through its coefficient values of 0.0147 it demonstrates a low impact of the extreme events of the past on the current volatility of the covariance between the series.

The parameter $dcc\beta$ with its coefficients of 0.9691 shows a persistent conditional volatility of the covariance between the series and its high values tends to be maintained over time. What can be seen from the results of the DCC-GARCH model is that the variations in the price of oil depend on many factors, among which are: the political uncertainty in the key areas with oil resources, the replacement of oil with renewable resources where possible, which can be added the unfortunate events of recent times. The stock indices, on the other hand, are very sensitive and volatile to market information, especially to the events of recent years. To analyse the conditional correlation, we have graphically illustrated, for each pair of returns, the conditional correlation obtained through the DCC-GARCH model, and the results illustrated in Figure 2 showed the correlation trends between Brent crude with the BET, WIG, CAC40, FTSE100, AEX, DAX and ATX indices.

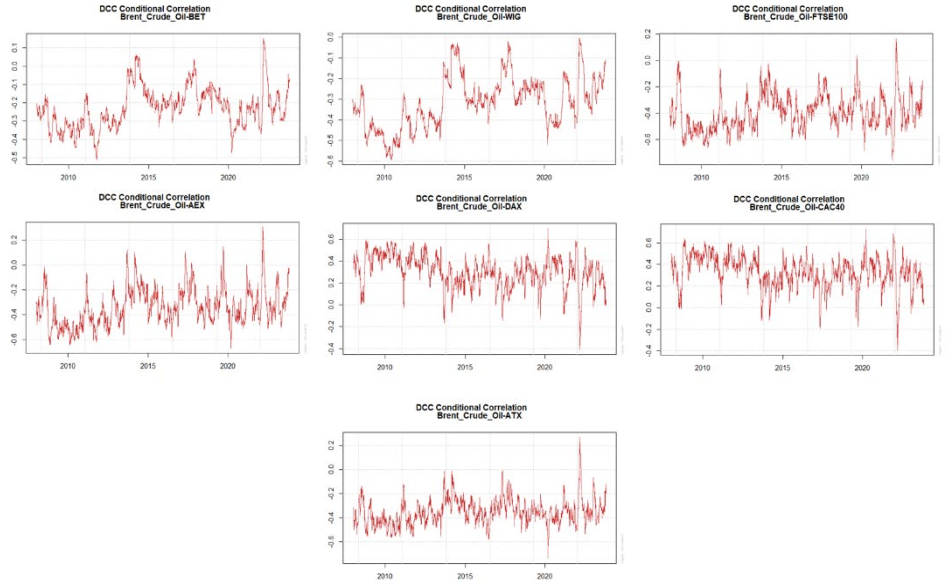

Figure 2. Conditional correlation between Brent Crude Oil and stock markets
Source: data collected from Yahoo Finance - own processing and calculations.

Analysing the graphs obtained, we can say that the impact of the events of recent years was stronger on the stock markets in France and Germany, to which the movements of the price of oil with the beginning of the military conflict between Russia and Ukraine were also added. The volatility graphs also show other variations in the prices of the stock indices and the price of oil, which indicate the spillover effect observed especially during the 2008-2010 crisis periods and other events unfavourable to the economy in the 2020-2023 period. The military conflict between Russia and Ukraine can be seen in Figure 2 where the need for oil was greater for countries such as France and Germany, and the graph shows an inverse conditional negative correlation between the indices of these countries and Brent Oil (on average of - 0.4).

5. Conclusions

Recent events have had a major impact on stock indices and oil. Political and economic uncertainty has led to low investor sentiment and much more reserved investment. The fact that the world is looking for new renewable resources and trying to adopt them will lead to a demand for oil and automatically affect the price of oil. Companies operating in the energy sector, especially those involved in the extraction and distribution of oil, based on these changes, must adapt to new market requirements, which affects the financial market.

This paper wanted to highlight the impact of current unfavourable events on stock market indices in Europe (Romania, Poland, France, Austria, Holland,

England, and Germany) and Brent Oil, with the Baltic Dry index as a control variable. The results obtained show that the events of recent years played an important role in increasing volatility and price movements, both for stock indices and for oil prices. Although the price of oil from the resulting increase does not have a strong correlation with the stock markets, it still has a major influence on the financial market, because the variations in the price of oil feed into the costs of consumer goods. The COVID-19 pandemic, from the findings obtained in the paper, highlights a strong impact on the price of oil, but also on the prices of stock indices. The volatility recorded during this period reached maximum levels that have not been met in the last 15 years. The military conflict between Russia and Ukraine, although it generated a smaller impact on oil prices and stock indices, greatly affected the Baltic Dry Index (BDI), due to disruptions in maritime transport and economic uncertainties generated by the conflict.

The correlation coefficient of results by growth generates that there are strong positive and negative correlations between stock markets and weaker correlations between oil and markets. The significant volatility associated with indices such as BDI (Baltic Dry Index) and Brent Oil highlight significant price fluctuations. This is important for investors to hedge portfolio risk, but also to make more informed decisions. In conclusion, it can be said that unfavourable events have a strong impact on the analysed stock indices but also on the Brent Oil and Baltic Dry indices, which can be seen from the results obtained by applying the DCC-GARCH model.

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