Pandemics, Conflicts, and Energy Transitions: Insights on Oil and Stock Market

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Abstract

The price of oil, and consequently, stock market indices, have been affected in recent years by factors weighing on the global economy, from energy market developments to the transition to renewable energy sources and changes in global energy policy. This paper offers a comprehensive analysis, from January 2004 to 2024, of the evolution of stock market indices, oil market volatility, and investor reactions to recent "black swan" events that have shaken the global economy. In other words, our research explores the complex link between oil price fluctuations and stock market performance in the G20 economies over the past decade. The econometric and statistical modeling applied by the paper highlights a complex relationship between the stock indices studied and the volatility of oil prices in a univariate GARCH modeling environment (GARCH (1.1)), and a multivariate time series model DECO-GARCH, corroborating specialized studies in the field by suggesting that oil price fluctuations were faster at the beginning of the COVID-19 pandemic with decreasing fluctuations after war events (beyond which no substantial impact of the oil price on the stock market is observed). In addition, the Chow test identified, during the period studied, three important breaks coinciding with the beginning of the COVID-19 pandemic, the subsequent military conflict between Russia and Ukraine and the military confrontation between Israel and Gaza, which had strong repercussions on the economy. The results also indicate another very important point: the COVID-19 pandemic had a greater impact on the oil price and the stock market between January 2019 and November 2024 than military conflicts.

Keywords : Oil prices, stock market returns, G20 countries, energy transition, DECO-GARCH.

1. Introduction

Until now, oil has remained a vital component of the economy, regardless of the number of renewable energy alternatives currently being exploited. Fluctuations in oil prices do not go unnoticed by financial markets; on the contrary, they have a direct impact on stock market indices and the behavior of financial markets in general. High oil prices appear to have a direct and negative effect on the economy, although in some cases the correlation between oil price fluctuations and stock market performance is minimal.

Energy is a key factor in global economic development, particularly in the oil sector. As such, this energy source is the backbone of industries in all countries. According to the Statistical Review of World Energy, oil accounted for 33.1% of global primary energy consumption in 2019. Therefore, any change in oil prices can have a significant impact on the economic growth and stability of both developed and developing countries. Over the past two decades, oil prices have exhibited extreme volatility, rising from $60 to $145 between mid-2007 and mid-2009. Subsequently, in 2014 and 2015, oil prices fell by nearly 75%, while during the pandemic, they fell to less than $20 per barrel. More recently, from December 2021 to March 2022, prices rose from $71 to $130.

The link between oil prices and stock market returns continues to generate considerable interest in research, policy discussions, and among investors, particularly in the G20 countries, which appear to be major players in the global economy, with significant oil producers and consumers and well-developed financial markets. Oil prices have considerable consequences for global economic growth, inflation, and corporate profitability, all of which weigh heavily on stock market performance. For example, shocks transmit between international oil prices and stock market returns. Oil price volatility has sectoral effects, particularly for industries that rely heavily on energy inputs, influencing valuations in different ways. Moreover, the same geopolitical events and global economic trends that shape these relationships induce simultaneous movements in oil prices and stock markets, raising questions about causality and directionality.

The hypothetical dependence between these different variables can act as both a positive and an opposing force. The economies of both oil-exporting and oil-importing countries are highly dependent on oil prices, and fluctuations in these prices have a major impact on their economies. The volatility of crude oil and alternative energy resources can have an immediate impact on investment returns in the stock market. The relationship between stock market values and oil prices has received considerable attention in recent years.

For example, the IEA estimates that oil will account for 30% of global energy supply by 2030. Investors, particularly portfolio managers, face disruptions due to unpredictable oil prices, which imposes risks and uncertainties on their investments. Research indicates that oil prices affect stock markets directly by altering future cash inflows, or indirectly through impacts on interest rates that value these cash inflows. Studies have shown that high oil prices can weigh on stock market performance by reducing potential economic growth through higher input costs, lower corporate revenues, and increased general price inflation. The additional uncertainty associated with high oil prices, which translates into high risk premiums, also depresses stock prices.

However, changes in stock markets are transmitted through different channels. Stock prices are influenced by oil prices, both by the cost of capital and by expectations about future cash flows. The increase in corporate cash flows is reduced by the increase in production costs due to rising crude oil prices, which lowers stock prices. Analyzing the correlation between crude oil and traditional stock markets provides important information to investors. The precariousness of the international crude oil market can delay investment decisions, as uncertainty in the oil market can have a profound impact on stock markets and the economy in general.

Uncertainty related to oil market challenges and risks is transmitted to the real economy, creating ripple effects that also affect capital markets and stock returns worldwide, in both developed and developing countries. The role of the G20 as a major economic and governmental group has considerable influence on global energy markets and the economy as a whole. The heavy dependence of G20 economies on energy exports and imports makes them vulnerable to oil prices and their volatility, with potential ramifications for the G20 region and its financial markets, particularly stock returns. Market fluctuations resulting from significant increases and decreases in oil prices in recent years underscore the importance of examining the causal relationships between stock market performance and oil price volatility.

Indeed, the main oil consumers are not limited to the United States, China, Japan, and India; countries such as Canada, Russia, and Brazil are also major producers. These countries largely dominate global energy markets. Given that the G20 countries are heavily affected by global crises and events such as the coronavirus pandemic, it should be easier to distinguish the effects of oil price shocks on their stock market returns. The global situation has worsened considerably, and global demand is more precarious than ever. The crisis has had negative consequences not only on human health but also on lifestyles and production. The measures taken by all countries to limit the spread of the epidemic have led to economic lockdowns and stock market crashes, which has led to a global economic slowdown and a collapse of the energy market. Given the significant fluctuations in oil prices in recent years, research should focus on the effects of these price changes on stock market performance.

Our research aims to highlight potential links between oil fluctuations and financial markets, particularly by assessing how disruptions and turbulence are transmitted from the oil market to the stock market. The study's findings will provide investors with valuable insights to navigate the complexities of global financial markets, enabling them to make informed decisions regarding potential oil price fluctuations. Further research could lead to more effective and practical policy solutions aimed at mitigating the negative effects of oil price volatility on economic outcomes. This research also contributes to existing work on commodity market interactions and examines the unique characteristics of G20 economies in a global context.

The objective of our study is to highlight the correlations between oil price volatility and financial sector fluctuations, focusing on how oil price shocks affect overall stock market performance. This research explores the relationship between stock market performance and oil prices, particularly the impact of fluctuations on oil-exporting and oil-importing countries. Changes in oil price volatility are associated with changes in stock market volatility, which fluctuate over time. The influence of the connection can be observed both positively and negatively at different times, sometimes moving together and other times diverging. The correlation between oil price movements and stock market fluctuations differs in magnitude between oil-exporting and oil-importing countries. We analyze WTI oil price and stock market return data from 16 G20 countries.

The findings of this research will provide investors with substantial information that will enable them to make informed decisions regarding market fluctuations and global financial investments in response to oil price changes. Future studies could contribute to the development of more effective and practical policy strategies to mitigate the negative effects of oil price fluctuations on economic outcomes. This research also contributes to the current literature by exploring the dynamics between commodity markets and identifying the individual characteristics of G20 economies within a broader global framework.

2. Literature review

Many studies have examined how changes in oil prices affect stock markets. One study by Park and Ratti (2008) found that fluctuations in oil prices led to changes in stock prices in 13 European countries. Another study by Kilian and Park (2009) showed that the US stock market was affected by both changes in oil supply and demand, with changes in demand having a greater impact.

Other research has examined how oil price changes influence stock markets globally. Wen et al. (2012) found that during the 2008 financial crisis, sharp fluctuations in oil prices affected the US and Chinese stock markets. Ghorbel and Boujelbene (2013) showed that these fluctuations also impacted stock markets in many countries, including those in the Middle East, Brazil, Russia, India, and China. Furthermore, Büyükşahin and Robe (2014) suggested that future studies should examine how economic crises alter the relationship between oil prices and stock prices.

Guesmi and Fattoum (2014) found that significant changes in the global economy affected the relationship between oil prices and stock prices in oil-importing and oil-exporting countries. This relationship strengthened during the financial crisis.

The MENA countries studied by Bouri (2015) included Lebanon, Jordan, Tunisia, and Morocco between 2003 and 2013. Before the financial crisis, the data indicate that there was limited interdependence in the transfer of volatility between oil and stock markets in these countries. During the post-crisis period, some links with monetary growth could be observed.

Du and He (2015) studied the cross-effects of risk between oil markets and stock markets using data from September 2004 to September 2012. Their research indicates that before the financial crisis, the stock market had a positive effect on the oil market, while the oil market exerted a negative influence on the stock market. In the post-crisis period, cases of mutual risk transmission were observed.

Several researchers, including Khalfaoui (2015), collaborated on a study. A limited number of studies specifically analyzed the G7 countries. The researchers used a multivariate GARCH approach combined with wavelet analysis to examine the correlation between West Texas Intermediate (WTI) oil prices and the stock markets of the Group of Seven (G7) economies. The study reveals a significant risk transfer between the oil market and the stock market, where increased fluctuations in the oil market primarily lead to increased uncertainty in the stock market.

Several studies have examined this relationship across different regions. Roberto and colleagues (2017) studied six Latin American countries (Argentina, Brazil, Chile, Colombia, Mexico, and Peru) from 2000 to 2015. They found that rising oil prices generally led to higher stock returns, regardless of whether the country was a major oil exporter or importer.

Horobet and his team (2019) studied the link between the European Union's financial sector and the oil market from 2010 to 2018. Their research showed that financial sector stocks were affected by changes in the price of oil over long periods. The Middle East, as a major oil-producing region, has also been the subject of studies exploring the link between oil and stock markets, particularly in the Gulf Cooperation Council (GCC) countries. Ammar and Mahmoud (2020) analyzed the Dubai market from 2010 to 2018 and found that oil market volatility influenced the volatility of energy sector stocks.

Lin et al. (2019) showed that oil price changes directly affected Chinese and European stock markets during periods of market irregularities. All these studies highlight that large oil price changes can have a considerable impact on stock markets, especially during periods of economic difficulties.

Finally, Abdulrahaman (2020) studied the long-term relationship between oil and stock markets in Saudi Arabia, a major oil exporter, using data from 2000 to 2017. His research confirmed the existence of a strong link between the two markets.

The results of this research indicate that oil price fluctuations are the primary channel through which volatility affects stock market movements. The data do not distinguish between oil-importing and exporting countries. A thorough understanding of conventional stock markets can help investors make informed decisions under different scenarios. Research conducted after commodity liberalization revealed a direct correlation between crude oil markets and various global stock markets. Applying the DCC-GARCH model to the relationship between oil prices and stocks has advantages because it adopts a multivariate approach that captures the mutual effects on volatility between the oil market and the stock market. However, this approach is not always sufficient to account for the complex dynamics inherent in these relationships.

This is where the DECO-GARCH model comes in, complementing the DCC-GARCH model. The latter is particularly adept at modeling time-varying correlations, taking into account asymmetries and leverage effects. By integrating these aspects, the DECO-GARCH model allows for a more detailed analysis of the interactions between oil and stock markets, providing a better understanding of the observed fluctuations. Thus, the joint use of the DCC-GARCH and DECO-GARCH models could enrich our understanding of the relationships between oil prices and stock markets, facilitating more precise generalizations depending on whether we consider countries dependent on oil exports or imports.

3. Methodology

Understanding and measuring volatility is not a straightforward process. Market anxiety is focused on several aspects, including a single, particularly relevant occupancy factor. This also helps determine how shocks are transmitted between different markets. Shocks and volatility between the oil and stock markets of selected G20 countries, such as Japan, Mexico, and Russia, were analyzed using two models from the GARCH family. These results should provide accurate and relevant data, often made possible by previous studies.

We began our work with the BEKK GARCH model, which is known for its complexity and applicability in the study of bidirectional effects. In addition, the DCC GARCH model is recognized for its superior results. Recent studies have used this model, which confirms its relevance (Tsuji, 2018; Fills et al., 2011). Among the specifications of dependent volatility, single-variable models, such as the well-known asymmetric GJR model and the exponential GARCH (EGARCH) model, can be derived from the DCC model, the latter incorporating the asymmetric leverage effect proposed by Nelson (1991).

The BEKK-DCC model could be modified to account for asymmetry and leverage effects, as well as the different variance and correlation attributes commonly observed in financial returns. The use of the DECO-GARCH models for valuation could be combined with the BEKK-GARCH and DCC-GARCH models to perform a comprehensive analysis of volatility and correlation dynamics in financial markets.

We chose the DECO-GARCH model because of its ability to account for time-varying correlations between oil prices and stock indices, accounting for investments in very different market conditions. This model allowed us to explain how shocks penetrate through more precise channels, as well as the volatilities observed with previous models. The results enrich our understanding of the complex interactions between factors at the market level.

However, the DECO-GARCH model also takes into account asymmetries and leverage effects, which allows us to better understand the subtleties of financial market behavior.

The BEKK model:

Multivariate GARCH models, known as the BEKK class, were introduced by Engle and Kroner (1995). Bauwens et al (2006) propose a general formulation that takes into account certain factor structures (see in particular, e.g., the year of publication of their work). In this paper, we consider the simplest BEKK formulation with all model orders fixed at:

$$\Sigma t = CCj + A\varepsilon t-1\ \varepsilon tj-1Aj + B\Sigma t-1Bj$$

Where A and B are two (N*N) matrices of constant parameters and C' is an (N*N) matrix of symmetric parameters. The fully parameterized model has 2.5N^2 + 0.5N parameters.

The DCC model:

Engle (2002) presented the DCC model as a broader adaptation of Bollerslev's (1990) conditional consistent correlation (CCC) model. The intention here is to model conditional variances and conditional correlations individually. The covariance matrix is decomposed according to the following formula.

$$\sum t = D_t \ R_t \ D_t$$

$$D_t = diag\ (\ \sigma_1 , t, \sigma_2 , t, \dots \dots \sigma_k , t)$$

$$R_t = Q_t^{1/2}\ Q_t\ Q_t^{1/2} \ ; \ Q_t = dg(Q_t)$$

Where Qt comprises the conditional variances characterized by a series of univariate GARCH equations (see Baba et al. (1990); Engle (2002)). The dynamic correlation matrix, Rt, does not come directly from a dynamic equation, but is derived from the normalization of a different matrix, Qt, which has a dynamic structure. The configuration of Qt defines the complexity and feasibility of the model in high cross-sectional dimensions.

Proposals for specifications of Qt have been formulated. The following analysis focuses only on the least complicated model and applies only to the BEKK specifications of equations (1) to (4). The Hadamard DCC model, also called the DCC model, was first introduced by Engle in 2002.

$$Q_t = S + A * \ D_{t-1}\, \varepsilon_{t-1}\, \varepsilon_{t-j}\ D_{t-1} - \sum S \ + B * (Q_{t-1} - S)$$

With A and B as symmetric parameter matrices and S as long-term covariance matrix.

The DECO-GARCH model:

The DECO-GARCH (Dynamic Conditional Correlation GARCH) model combines features of the GARCH family of models and dynamic conditional correlation methodologies. Here is a general representation of the DECO-GARCH model:

$$r_{it}= +\mu \epsilon_{it}$$

where r it is the return on asset i at time t, μi is the average return and ϵit is the residual (or shock).

$$\epsilon_{it}=\sigma_{it} z_{it}$$

where zit is a white noise process (usually assumed to be normally distributed)

$$\sigma_{it}^2= + +\alpha_0 \alpha_1 \epsilon_{it-1}^2 \beta_1 \sigma_{it-1}^2$$

Where α_0 and β_1 are the parameters of the GARCH model.

where Dt is a diagonal matrix of conditional standard deviations σ_it and Q_t is the dynamic covariance matrix defined as follows:

$$Q_t = S + A(\epsilon_{t-1} \epsilon_{t-1}^T) + \mathrm{B}(- \mathrm{S}) Q_{t-1}$$

Here, S is the long-term covariance matrix, and A and B are parameter matrices.

4. Data and descriptive statistics

4.1. data

We analyzed data for the two series in question oil prices and stock market returns from the G20, which consists of 16 countries such as Australia, Brazil, Canada, China, France, Germany, India, Italy, Japan, Mexico, Russia, South Africa, South Korea, the United Kingdom, Turkey, and the United States. In the BEKK-GARCH model analysis, the years 2004 to 2024 were classified into five distinct intervals. From 2004 to 2007, a period of stability preceded the subprime crisis. The subprime crisis occurred between 2008 and 2009. Between 2010 and 2014, the transition from the subprime crisis to the debt crisis took place, culminating in the 2014 oil crisis. The years 2015 to 2019 were marked by global and universal financial stability. The COVID health crisis and Russia's invasion of Ukraine from 2020 to 2024. However, the DECO-GARCH model analysis included the entire period.

This data was collected from Data Stream (a global financial and macroeconomic data platform) and the international database The Global Economy.

4.2. Descriptive statistics

	WTI	SIAUS	SIBR	SICA	SICH	SIFR	SIGER	SIIND

Mean	0.006813	0.003753	0.009067	0.003964	0.005761	0.003105	0.004792	0.011041
Median	0.014827	0.008181	0.011651	0.010836	0.000921	0.009164	0.013215	0.018394
Maximum	0.728814	0.103200	0.200413	0.109348	0.213908	0.106783	0.139292	0.220859
Minimum	-0.447122	-0.222921	-0.280195	-0.221203	-0.195488	-0.245601	-0.245390	-0.240469
Std. Dev.	0.110172	0.036991	0.060911	0.036843	0.066295	0.043721	0.047034	0.054451
Skewness	0.681695	-1.609310	-0.806945	-2.240944	0.401592	-1.563778	-1.502868	-0.629307
Kurtosis	13.53196	10.36139	6.290208	14.85418	4.268968	9.276804	8.854649	7.130637
Jarque-Bera	944.5410	540.6032	112.4771	1345,099	18.88885	411.8815	362.7326	156.1625
Probability	0.000000	0.000000	0.000000	0.000000	0.000079	0.000000	0.000000	0.000000
Sum	1.369365	0.754279	1.822367	0.796774	1.157987	0.624119	0.963130	2.219212
Sum Sq. Dev.	2.427590	0.273667	0.742023	0.271480	0.879015	0.382308	0.442434	0.592981
Observations	201	201	201	201	201	201	201	201

	SIITA	SIJAP	SIMEX	SIRUS	SISAF	SISKOR	SITUR	SIUKING	SIUSA
Mean	0.00076	0.00331	0.00801	0.01048	0.00885	0.00609	0.01117	0.002044	0.004216
Median	0.00584	0.00640	0.01104	0.01576	0.01500	0.00973	0.01511	0.005745	0.010500
Maximum	0.18303	0.10371	0.13378	0.18220	0.07437	0.15923	0.18698	0.088798	0.126605
Minimum	-0.26430	-0.21957	-0.19152	-0.38059	-0.19895	-0.17549	-0.22643	-0.214878	-0.224787
Std. Dev.	0.05173	0.04781	0.04408	0.06527	0.03866	0.04406	0.06350	0.036727	0.039460
Skewness	-0.98230	-0.80481	-0.72613	-1.32672	-1.56614	-0.78610	-0.31197	-1.777610	-2.044221
Kurtosis	7.52766	5.14891	5.21863	9.32853	8.69577	5.72779	4.06934	11.16674	13.05484
Jarque-Bera	204.010	60.3731	58.8885	394,387	353,869	83.0188	12.8372	664.4323	986.7019
Probability	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00163	0.000000	0.000000
Sum	0.15346	0.66525	1.61052	2.10651	1.77998	1.22549	2.24573	0.410784	0.847391
Sum Sq. Dev.	0.53529	0.45731	0.38862	0.85205	0.29898	0.38841	0.80657	0.269774	0.311418
Observations	201	201	201	201	201	201	201	201	201

The descriptive statistics presented in the table concern daily returns based on oil and stock indices. The pre-pandemic and pandemic eras are divided into several periods: pre-recession, crisis, post-recession, and crisis. Data on level, risk, standard deviation, change over time, as well as minimum and maximum values, provide a valuable overview.

Following the successive crises that impacted the oil and stock markets, the majority of indices displayed unfavorable values. The series studied allow for testing normality using the "Skewness" and "Kurtosis" coefficients, as well as the Jarque-Bera test statistic. The "Kurtosis" coefficient measures the degree of flattening of the distribution, a normal distribution being characterized by a value equal to three. A value less than three indicates a flatter-than-normal distribution, while a value greater than three suggests a leptokurtic distribution.

The skewness coefficient quantifies the degree of asymmetry of the distribution. A negative value indicates a distribution that leans to the left, while a positive value indicates a slope to the right. A value of zero means the distribution is balanced and follows a normal distribution. The null hypothesis of the Jarque-Bera test states that the data follow a normal distribution. If the estimated value of the k-squared statistic exceeds the value specified for the test, the hypothesis is rejected.

5. Empirical results

5.1. Stationarity test: Augmented Dickey-Fuller (ADF)

To understand how data changes over time, we first need to make sure it behaves in predictable ways. This is called checking for "stationarity." We use a special test called the ADF test, which helps us determine whether our data is stable or not, even if it appears to be changing a lot. This test helps us get a better idea of how reliable our data is for studying changes over time.

	SIAUS	**SIBR**	**SICA**	**SICH**	**SIFR**	**SIGER**	**SIIND**	**SIITA**
ADF test in level	-11.31345 0.0000***	-10.05088 0.0000***	-11.21867 0.0000***	-9.221951 0.0000***	-11.46416 0.0000***	-11.54625 0.0000***	- 10.230610.0000***	-11.81599 0.0000***
ADF first difference test	- 11.83443- 0.0000***	-11.73217 0.0000***	- 12.57950- 0.0000***	-15.51194 0.0000***	-9.692905 0.0000***	-9.796026 0.0000***	-12.88532 0.0000***	-12.51546 0.0000***
	SIJAP	**SIMEX**	**SIRUS**	**SISAF**	**SISKOR**	**SITUR**	**SIUKING**	**SIUSA**
ADF test in level	-11.14152 0.0000***	-11.47700 0.0000***	-9.894833 0.0000***	-11.99281 0.0000***	-10.92912 0.0000***	-10.89029 0.0000***	-12.49528 0.0000***	-11.14580 0.0000***
ADF first difference test	-13.55871 0.0000***	-14.42846 0.00[illegible]**	-15.15411 0.0000***	-9.895130 0.0000***	- 9.6886810.0000***	-13.05923 0.0000***	-13.03901 0.0000***	-14.29963 0.0000***

Note(s): ***, **, * statistical significance at 1%, 5 and 10% levels, respectively

5.2. Automatic Vector Regression (VAR) Test

Vector autoregression (VAR) is a powerful tool for understanding how different economic factors, such as inflation, unemployment, and interest rates, affect each other over time. It is a system of equations that shows how these factors are related. For example, if inflation rises, VAR can help us see how this might affect unemployment and interest rates. The point is not to assume that one factor causes another, but to examine how they affect each other. This makes VAR a flexible tool for understanding complex relationships in the economy.

	SIAUS	**SIBR**	**SICA**	**SICH**	**SIFR**	**SIGER**	**SIIND**	**SIITA**
Lag (1)	(0.682820) 2.98678***	(0.494898) 3.51950***	(1.194674) 5.21337***	(0.183159) 1.44766	(0.635556) 3.46356***	(0.618769) 3.67097***	(0.441845) 2.92883***	(0.478478) 3.09398***

Lag (2)								
	(-0.519184) -2.24309**	(-0.206186) -1.44985	(-0.388098) -1.59487	(-0.09351) -0.74253	(-0.485421) -2.60233***	(-0.3781) -2.19122**	(-0.371497) -2.4711***	(-0.348812) -2.22377**
	SIJAP	**SIMEX**	**SIRUS**	**SISAF**	**SISKOR**	**SITUR**	**SIUKING**	**SIUSA**
Lag (1)	(0.386582) 2.28087**	(0.47173) 2.5147***	(0.441596) 3.38716***	(1.003438) 4.91113***	(0.823615) 4.53435***	(0.328258) 2.59288***	(0.805366) 3.7126***	(0.904141) 4.34468***
Lag (2)	(-0.217494) -1.2714	(-0.364704) -1.92433*	(-0.096434) -0.71955	(-0.190675) -0.87921	(-0.292946) -1.55113	(-0.189414) -1.47995	(-0.434526) -1.93969*	(-0.472278) -2.21189**

Note(s): ***, **, * statistical significance at 1%, 5 and 10% levels, respectively

The VAR model analysis shows that a one-period lag in oil prices has a positive and significant impact on stock returns for most countries, including Australia, Brazil, Canada, France, Germany, India, Italy, Japan, Mexico, Russia, South Africa, South Korea, Turkey, the United Kingdom, and the United States, except China. This result is consistent with previous research by Roberto et al. (2017).

However, when the oil price is lagged by two periods, the impact on stock returns becomes negative and significant for a smaller group of countries, including Australia, Germany, India, Italy, and the United States. For the remaining countries, the impact is negative but not statistically significant. This result is consistent with previous studies by Filis et al. (2011) and Khan et al. (2019). It is important to note that the results for the first lag (one-period lag) are generally more relevant than those for the second lag (two-period lag). This is because the immediate consequences of oil price shocks are fully reflected in the first lag, while these effects are attenuated in the second lag.

5.3 Analysis of the correlation between the price of crude oil and the G20 stock market indices

The BEKK model, proposed by Baba, Engle, Kraft, and Kroner (1995), is known to be the most comprehensive and computationally convoluted of the models considered for this study. The results in Figure 8 illustrate the effects of incorporating oil shocks on the performance of different stock indices in our selected bivariate BEKK-GARCH model. The period was divided into five unique sub-periods. The first interval runs from January 1, 2004 to June 30, 2007, while the next one runs from July 1, 2007 to December 31, 2009, followed by another interval from January 1, 2010 to December 31, 2014, then another interval from January 1, 2015 to December 31, 2019, and finally a last interval from January 1, 2020 to January 1, 2021. This paper examines the volatility transmission between oil markets and stock markets of 16 G20 countries divided into oil-exporting countries and countries including oil-exporting countries over five unique sub-periods.

The transmission is quantified in two phases by α_2,1 and the variance is represented by β_2,1. Three different significance levels are studied: one percent, five percent, and several percent. The ARCH coefficients measure the impact of delayed shocks while GARCH explains how volatility affects the equation. The results of the BEKK-GARCH analysis show that both ARCH and GARCH effects are substantial in the oil and stock markets.

a- Analysis of results for importing countries

Period 1: 2004-2007 before the subprime crises

Countries	Australia	Brazil	Canada	China	France	Germany	India	Italy
$\alpha_{1,2}$	(0.169597216)	(0.05877782)	(0.116275985)	(-0.06208051)	(0.03767483)	(-0.09130473)	(0.141097745)	(0.114155928)
	0.01518284**	0.61825417	0.17805003	0.49479682	0.65624020	0.41291163	0.21186811	0.22540396
$\alpha_{2,1}$	**(1.654782729)**	**(-0.36805293)**	(0.390316497)	**(-0.97635438)**	(-0.2300705)	(-0.2394867)	(-0.282727397)	(-0.514984745)
	0.00968508* **	**0.06716381***	0.62253815	**0.0006742*** **	0.74310132	0.64728079	0.32347168	0.38707364
$\beta_{1,2}$	(0.202658597)	(-0.1804604)	(0.054327556)	**(-0.59129083)**	(-0.00103684)	(-0.04101038)	(-0.091468981)	(-0.164737136)
	0.00841906***	0.0000031***	0.43950938	**0.0000439*** **	0.98838929	0.41504148	0.45663033	0.14092334
$\beta_{2,1}$	**(2.463787408)**	**(0.26959268)**	(-1.076989534)	**(-0.58214004)**	**(-1.64296696)**	**(-1.03020196)**	(0.219497394)	(0.154874933)
	0.00081607* **	**0.0014616*** **	0.1912885	**0.0094340*** **	**0.0072258*** **	**0.04714491** **	0.39915079	0.91892794

Period 2: 2008-2009 the subprime crises

Countries	Australia	Brazil	Canada	China	France	Germany	India	Italy
$\alpha_{1,2}$	(-0.088484494)	(-0.04852523)	(0.03981804)	(0.16391328)	(-0.21192893)	(-2.47572676)	(-0.9028)	(-8.2139e-03)
	0.23127608	0.56726119	0.55905529	0.0095533***	0.04594817**	0.0000000***	0.00000000***	0.00000001***
$\alpha_{2,1}$	**(-1.019532424)**	**(-1.07727442)**	**(1.678801628)**	**(-0.47705689)**	**(0.43774818)**	**(0.92545761)**	**(0.1327)**	**(0.2469)**
	0.00008945* **	**0.0001345*** **	**0.00118638*** **	**0.30095772**	**0.04168180** **	**0.0000000*** **	**0.00000000*** **	**0.00000000*** **
$\beta_{1,2}$	(-0.16821894)	(-0.11805167)	(-0.206672244)	(0.201490849)	(-0.38726908)	(-0.01461998)	(0.4002)	(0.2402)
	0.19645864	0.45999088	0.00072169***	0.21488241	0.0000000***	0.06138959*	0.00000000***	0.00000000***
$\beta_{2,1}$	**(-0.646021254)**	**(-0.44903077)**	**(1.087060641)**	**(1.01273258)**	**(0.6721346)**	(0.00513251)	**(0.1955)**	**(0.2035)**
	0.02412485 **	**0.08148306***	**0.04658286** **	**0.07657895***	**0.0000000*** **	0.1270042	**0.00000000*** **	**0.00000309*** **

Period 3: 2010 -2014 after the subprime crises and on theSovereign debt crisis

Countries	Australia	Brazil	Canada	China	France	Germany	India	Italy
$\alpha_{1,2}$	(0.132698966)	(-0.48163288)	(0.023698546)	(-0.10363660)	(0.23725172)	(0.34502674)	(-0.252033511)	(0.417888805)
	0.07887568*	0.0002231***	0.72654426	0.33341714	0.03931942**	0.0021888***	0.00406265***	0.00023534***
$\alpha_{2,1}$	(0.109813916)	**(0.58939818)**	**(1.177612153)**	**(0.77049669)**	**(1.87535075)**	**(2.31959778)**	**(0.732344154)**	(0.082522089)
	0.76098620	**0.0059907*** **	**0.00032657*** **	**0.01041155** **	**0.0071684*** **	**0.0000000*** **	**0.00091239*** **	0.77651123
$\beta_{1,2}$	(0.246884312)	(0.28028483)	(0.276047027)	(-0.14903503)	(0.03564804)	(-0.00986098)	(-0.148293055)	(0.345025627)
	0.00094687***	0.17080017	0.00066263***	0.52190468	0.77842593	0.91148162	0.03431159**	0.00426592***
$\beta_{2,1}$	**(-1.317857651)**	**(-0.90497577)**	**(-0.513797813)**	(-0.22580676)	**(0.67706337)**	**(0.57412898)**	**(0.331816235)**	**(-0.814393585)**
	0.00000000* **	**0.0019739*** **	**0.07081295***	0.65567468	**0.0000343*** **	**0.0000004*** **	**0.03092979** **	**0.00010788*** **

Note(s): ***, **, * statistical significance at 1% , 5 and 10% levels, respectively

Period 4: 2015-2019 before COVID-19								
Countries	Australia	Brazil	Canada	China	France	Germany	India	Italy
$\alpha_{1,2}$	(-0.208841593)	(-0.00994103)	(-0.157164953)	(-0.1761913)	(-0.17555448)	(-0.2085324)	(0.012373638)	(-0.286751766)
	0.00000006***	0.91445574	0.01063880**	0.04758599**	0.0005954***	0.0004671***	0.79718606	0.04930797**
$\alpha_{2,1}$	**(2.119996952)**	**(0.69774481)**	**(1.771425028)**	**(-0.66997731)**	**(1.74552908)**	**(1.45438818)**	(-0.101279972)	**(1.300753303)**
	0.00000139* **	**0.0015485*** **	**0.00010945*** **	**0.01138941** **	**0.0000027*** **	**0.0000213*** **	0.82270552	**0.00000324*** **
$\beta_{1,2}$	(-0.006792305)	(-0.35277126)	(0.188201227)	(-0.19042913)	(0.3553212)	(-0.22824673)	(-0.138685438)	(0.028248952)
	0.80154871	0.0000001***	0.00007816***	0.04964350**	0.0000069***	0.0021967***	0.02300313**	0.85308336
$\beta_{2,1}$	(0.175208863)	**(0.64265948)**	(-0.515641162)	**(0.57775992)**	**(-1.83542528)**	**(1.23724630)**	**(2.465201662)**	(-0.757196580)
	0.66110155	**0.0000206*** **	0.62058348	**0.0005418*** **	**0.0000001*** **	**0.07175053* **	**0.00000000*** **	0.48959280
Period 5: 2020 -2021 the COVID-19								
countries	Australia	Brazil	Canada	China	France	Germany	India	Italy
$\alpha_{1,2}$	(-0.477091562)	(0.049127390)	(-0.462383259)	(-0.03684975)	(-0.38278084)	(0.02626215)	(-0.085750679)	(-0.255296741)
	0.00000000***	0.12419103	0.00000000***	0.29608677	0.0000000***	0.0000000***	0.00000000***	0.00000000***
$\alpha_{2,1}$	**(4.332756787)**	**(0.62702503)**	**(6.990584107)**	**(3.56421437)**	**(5.80258697)**	**(3.0944353)**	**(3.848406714)**	**(6.736233798)**
	0.00000000* **	**0.0005431*** **	**0.00000000*** **	**0.0000000*** **	**0.0000000*** **	**0.0000000*** **	**0.00000000*** **	**0.00000000*** **
$\beta_{1,2}$	(-0.012216566)	(0.01063818)	(-0.009020603)	(-0.00046059)	(-0.01053482)	(0.11371150)	(0.047138925)	(-0.023758603)
	0.30846432	0.56761257	0.00000000***	0.96708326	0.0000000***	0.0000000***	0.00000000***	0.00000000***
$\beta_{2,1}$	**(0.053369942)**	(0.06946938)	**(0.077423311)**	**(1.32254806)**	**(0.0472128)**	**(0.5113333)**	**(0.559194167)**	**(0.626585326)**
	0.00015037* **	0.32793668	**0.00000000*** **	**0.0000000*** **	**0.0000000*** **	**0.0000000*** **	**0.00000000*** **	**0.00000000*** **

Note(s): ***, **, * statistical significance at 1%, 5 and 10% levels, respectively

This study examined the impact of oil price changes on stock market returns in various oil-importing countries. During a period of rising oil prices, the study found that oil prices had a significant impact on stock market performance.

The analysis, which uses a statistical model called BEKK-GARCH, showed that before the 2008 financial crisis, changes in oil prices influenced both the average return and volatility of stock markets in Australia, Brazil, China, and Italy. This means that fluctuations in oil prices affected both the overall direction and the risk level of stock markets in these countries.

In contrast, in France and Germany, oil price changes only affected stock market volatility, not average returns. This suggests that while oil price fluctuations increased risk in these countries, they did not necessarily lead to higher or lower overall stock market returns.

Overall, the study showed that the impact of oil price changes on stock markets varied across oil-importing countries, with some experiencing both positive and negative effects. Crude oil is a very important commodity that has a significant impact on the economy. When oil prices rise, it becomes more expensive to produce goods and services, as well as transport and heat homes. This can lead to higher prices for consumers, which can cause them to buy less. When people buy less, it can harm businesses, make people less confident in the economy, and have a negative impact on the economy overall.

There are several reasons why oil prices can affect the stock market. One is that the value of a company's stock is based on its expected future profits. If oil prices rise, companies may have higher operating costs, which can reduce their profits. This could lead to a decrease in stock prices. However, rising oil prices can also mean that companies that produce oil will earn more money, which could lead to an increase in stock prices. Studies have shown that there is a link between oil prices and stock prices. This means that changes in oil prices can affect the stock market. This is what researchers Malik and Ewing (2009) and Arouri and Nguyen (2010) found in their studies.

Our study found no evidence of transmission from oil markets to stock markets in most of the countries we examined. This is consistent with previous research by Cong et al. (2008) and Jammazi and Alouli (2010). However, during the second period of our study, which coincided with the global financial crisis, we observed a significant impact on oil markets. The price of crude oil rose from $96 in January 2008 to $144 in July, likely due to the subprime mortgage crisis and its effects on oil supply. This sharp increase affected industries heavily dependent on fuel.

The combination of the global economic crisis and efforts by major oil-consuming countries to reduce their dependence on oil led to a dramatic drop in oil prices, which fell as low as $32 per barrel. Our analysis found that this period was marked by a transmission of effects from oil markets to stock markets in all G20 oil-importing countries, both in terms of average prices and volatility. Interestingly, the transmission was negative for Australia, Brazil, and China, while it was positive for the remaining countries.

When oil prices peaked in July 2008, the impact on stock markets was expected to be positive. Indeed, the price increase was due to strong global demand for oil. However, things changed after mid-2008, when the global financial crisis hit. The crisis strengthened the links between financial markets around the world, and the relationship between oil prices and the stock markets of oil-importing countries strengthened. As the crisis worsened, both stock and oil markets experienced a downturn, which had a negative impact on the stock markets.

The price of oil reached $80 a barrel in the early 2000s. This was partly due to oil-producing countries cutting production to cope with their economic problems. The global economy improved in 2010, which also contributed to the rise in oil prices.

However, things changed after mid-2008. The financial crisis of that year made global financial markets more interdependent. This strengthened the relationship between oil prices and stock market prices. The crisis led to a decline in stock markets and a sharp drop in oil prices.

Research shows that changes in oil prices can affect stock markets, especially in countries that import a lot of oil. This is similar to a study by Nazlioglu et al. (2015). They found that changes in oil prices affected financial markets before the 2008 crisis. After the crisis, they found that problems in financial markets could also affect oil prices. In 2015, the price of oil fell to $50 per barrel due to an oil surplus, mainly due to increased production in the United States. Although OPEC countries maintained their production levels, the price fell further, falling below $30 per barrel.

However, a few months later, the price began to rise slightly after some oil-producing countries decided to cut production. This period had a significant impact on both the oil and stock markets. The volatility in the oil market directly affected the stock markets of many oil-importing countries. The global price of oil fell dramatically in mid-2014. The price of Brent crude oil fell from $114 per barrel in June 2014 to $28 per barrel in February 2016, a drop of more than 70%. This sharp decline was caused by a combination of factors: the rapid growth of shale oil production in North America, fueled by technological advances, led to an excess of oil on the market, while weak economic growth in many countries led to a decline in demand for crude oil.

The year 2020 was marked by a major global crisis with the emergence of the COVID-19 virus. This pandemic triggered a global slowdown, with economies rapidly contracting. The price of oil plummeted to a record low, falling below $20 per barrel. This situation was particularly worrying for countries heavily dependent on oil revenues. Studies have shown a strong link between oil prices and stock market performance, particularly for oil-importing countries, such as those in the G20.

During the Period 1, oil price fluctuations had a varied impact on stock market returns in different oil-importing countries. Japan displayed a negative coefficient of -0.0786 for α_1.2, indicating that rising oil prices had a negative impact on stock market returns. Conversely, countries such as Mexico and South Korea displayed positive coefficients (0.0468** and 0.6076, respectively), suggesting that their stock markets benefited from rising oil prices, perhaps due to robust economic growth and strong demand. The United States displayed a particularly high coefficient (0.8665), reflecting a strong correlation between oil prices and positive stock market returns, likely due to investor optimism about the economy.

However, the results also indicate that oil price changes mainly influenced volatility in countries such as France and Germany, highlighting a more cautious sentiment among investors in these markets.

After in the second period, it was marked by a dramatic change as the global financial crisis unfolded. Japan's α_1.2 coefficient reached 0.7369, indicating that the stock market was positively influenced by oil prices despite the crisis.

'In contrast, the United States experienced a dramatic change, with oil price fluctuations leading to significant volatility, as indicated by the negative α_2.1 coefficient (-1.1782). This suggests that the financial crisis weakened the relationship between oil prices and stock market performance, leading to increased uncertainty. The coefficients for South Africa and Turkey are also highly significant, indicating that these markets were particularly sensitive to oil price fluctuations during the crisis, reflecting broader economic fears and reduced consumer demand.

Then, during the third period that recovery phase following the subprime crisis, results were mixed for oil-importing countries. Japan's α_1.2 coefficient remained positive at 0.2355, suggesting stability in its stock market in relation to rising oil prices. In contrast, Mexico's coefficient is low (0.0042**), indicating a weaker relationship, while countries such as South Korea and Turkey demonstrated resilience by reacting positively to rising oil prices.

In particular, the UK stock market reacted positively to changes in oil prices, as evidenced by its significant coefficient (0.5739). This period was marked by a gradual recovery, but some caution persisted as investors dealt with the lingering effects of previous crises.

After in the fourth "period, the coefficients for oil-importing countries exhibited a mixture of stability and volatility. Japan recorded a negative coefficient of -0.3335, indicating increased sensitivity to declining oil prices, which may reflect concerns about economic growth and demand.

In contrast, Mexico's coefficient remained stable at 0.0000, suggesting less sensitivity to oil price fluctuations. The United Kingdom and South Africa displayed positive coefficients (0.5429 and 0.0353**, respectively), indicating that their stock markets maintained favorable outlooks in response to rising oil prices. The mixed results across countries suggest that while some markets are stabilizing, others still face vulnerabilities related to oil price changes.

The final period was characterized by high volatility due to the COVID-19 pandemic and geopolitical tensions. Most countries exhibited negative coefficients, with Japan (-0.2238) and the United States experiencing a significant negative impact on stock returns in response to lower oil prices. The coefficients for Mexico and Turkey indicated a dramatic shift, reflecting how the pandemic exacerbated economic uncertainties and investor fears. The high α_2.1 value for Japan (2.4002) suggests that past oil shocks had a lasting impact on market behavior, highlighting the interconnectedness of oil prices and stock market performance during crises.

Overall, the results from this period reveal that global disruptions intensified the relationship between oil prices and stock market dynamics, with significant implications for investor sentiment. Overall, the analysis across time periods reveals a complex interaction between oil prices and stock market performance in importing countries. During periods of economic stability, rising oil prices typically boost stock market returns, signaling confidence in growth, while during crises, this relationship often reverses, with falling oil prices correlated with declining stock market performance. The lingering effects of past shocks highlight the influence of historical events on investor sentiment and the need for markets to adapt to the changing economic landscape. The results show that while some countries benefit from rising oil prices, others are more sensitive and vulnerable, particularly during periods of economic instability, reflecting the critical link between energy markets and broader economic conditions.

b- Analysis of results for exporting countries

Period 1: 2004-2007 before the subprime crises

Countries	Japan	Mexico	Russia	South Africa	South Korea	Turkey	United Kingdom	United States
$\alpha_{1,2}$	(-0.078614113)	(0.118139173)	(0.090898471)	(0.024565310)	(-0.015471428)	(0.298644868)	(0.093390965)	(0.068722648)
	0.04683363**	0.11838453	0.60764701	0.62296385	0.86654871	0.04347037**	0.28751143	0.16479182
$\alpha_{2,1}$	**(0.629441175)**	**(-2.046654616)**	**(-0.570704965)**	(-0.299380340)	**(0.989177744)**	(0.081494083)	(0.482239577)	**(1.631732194)**
	0.04228121**	**0.00000000*****	**0.05499495***	0.52687744	**0.00065098*****	0.75291683	0.44731582	**0.00498912*****
$\beta_{1,2}$	(0.050338795)	(0.012776838)	(0.560832485)	(0.296423264)	(0.095708620)	(-0.198037412)	(-0.002182587)	(0.043389611)
	0.00675580***	0.85571849	0.12375177	0.00000000***	0.23417511	0.04473297**	0.98441788	0.02811906**
$\beta_{2,1}$	(0.045329318)	(0.000022833)	**(-0.793421135)**	**(-1.524642491)**	(-0.083462599)	**(0.360575869)**	(1.421263015)	(-0.243810237)
	0.81567868	0.66588500	**0.00011313*****	**0.00000215*****	0.68882748	**0.05075932***	0.10750330	0.34272385

Period 2: 2008-2009 the subprime crises

Countries	Japan	Mexico	Russia	South Africa	South Korea	Turkey	United Kingdom	United States
$\alpha_{1,2}$	(0.736870)	(1.905891351)	(-0.4828)	(-0.255682150)	(2.872868155)	(1.704645662)	(0.733566370)	(0.990075141)
	0.00000000***	0.00000000***	0.02175166**	0.44298475	0.00000000***	0.00000000***	0.00956585***	0.00000000***
$\alpha_{2,1}$	**(-1.178209)**	**(-3.870827938)**	**(0.7983)**	(0.226935724)	**(-2.185993924)**	**(-1.249361306)**	(0.000427886)	**(-0.685673638)**
	0.00000000***	**0.00000000*****	**0.00000000*****	0.39406317	**0.00000000*****	**0.00000000*****	0.88273101	**0.00000000*****
$\beta_{1,2}$	(-0.275630)	(0.071544855)	0.4162	(0.687851839)	(0.184002179)	(-0.036585403)	(0.000238667)	(-0.059910751)
	0.03295570**	0.00000000***	0.00000000***	0.00000000***	0.00000000***	0.00000000***	0.99863318	0.26308020
$\beta_{2,1}$	**(-0.000030)**	**(0.051779347)**	**(0.4036)**	**(0.047515482)**	**(-0.051367532)**	**(-0.111789730)**	(-0.000152489)	(0.002644439)
	0.00000000***	**0.00000000*****	**0.00000000*****	**0.00000000*****	**0.00000000*****	**0.00000000*****	0.87345512	0.05328588/

Period 4: 2015-2019 before COVID-19

Period 3: 2010 -2014 after the subprime crises and on the Sovereign debt crisis

Countries	Japan	Mexico	Russisa	South Africa	South Korea	Turkey	United Kingdom	United States
$\alpha_{1,2}$	(0.235484924)	(0.129175514)	(0.085619930)	(0.269305965)	(0.274816236)	(-0.305297434)	(-0.024634476)	(0.010687475)
	0.00415880**	0.31332353	0.53628264	0.00000008***	0.00304131***	0.01145705**	0.57389825	0.88090202
$\alpha_{2,1}$	**(0.741362220)**	**(0.946708199)**	**(-1.056231161)**	**(2.148355505)**	**(1.523403063)**	**(0.778437494)**	**(0.897276963)**	**(1.397380759)**
	0.00259140* **	**0.00082963*** **	**0.00086158*** **	**0.00001024*** **	**0.00000002*** **	**0.00002074*** **	**0.00015000*** **	**0.00000475*** **
$\beta_{1,2}$	(-0.037826041)	(-0.335788406)	(-0.624162719)	(-0.101695146)	(0.018345071)	(-0.138625772)	(0.411457872)	(0.115832802)
	0.67119522	0.00067670***	0.00473837***	0.08499822*	0.88795741	0.47739579	0.00000000***	0.15014561
$\beta_{2,1}$	(-0.317796756)	**(0.780934117)**	(0.350511635)	**(-0.670527977)**	**(-0.655047913)**	(-0.373070609)	**(-1.920249931)**	**(0.443486676)**
	0.14723725	**0.00551131*** **	0.38615008	**0.01879517** **	**0.08504442***	0.34907580	**0.00000000*** **	**0.00673259*** **

Note(s): ***, **, * statistical significance at 1%, 5 and 10% levels, respectively

Countries	Japan	Mexico	Russia	South Africa	South Korea	Turkey	United Kingdom	United States
$\alpha_{1,2}$	(-0.333458450)	(0.091482568)	(-0.130495291)	(0.052813212)	(-0.144886642)	(0.204168958)	(-0.090327266)	(-0.184766909)
	0.00000002***	0.03534234**	0.01709291**	0.54296427	0.01331436**	0.01163456**	0.01633754**	0.00029484***
$\alpha_{2,1}$	**(1.260740101)**	**(-1.067431292)**	(0.191924464)	**(-1.839373478)**	**(-1.252690998)**	**(-0.585282064)**	(-0.122378159)	**(2.162645372)**
	0.00010189***	**0.01639655****	0.61075365	**0.00010838*****	**0.00082615*****	**0.04533999****	0.87175971	**0.00054887*****
$\beta_{1,2}$	(-0.119562008)	(0.009211532)	(-0.032591921)	(0.150708089)	(0.111312674)	(0.494753180)	(-0.182813531)	(-0.056742643)
	0.10412902	0.61907059	0.81322184	0.06148021*	0.28305473	0.00000000***	0.00015196***	0.28453314
$\beta_{2,1}$	(0.645365505)	**(-0.395127970)**	**(1.533809029)**	**(-1.131276466)**	**(1.491161958)**	**(1.287563812)**	**(2.550829986)**	**(2.585720915)**
	0.12287292	**0.02962722****	**0.06161001***	**0.04189184****	**0.00848143*****	**0.00249113*****	**0.00000140*****	**0.00000100*****

Period 5: 2020 -2021 the COVID-19

Countries	Japan	Mexico	Russia	South Africa	South Korea	Turkey	United Kingdom	United States
$\alpha_{1,2}$	(-0.223829)	(0.045375397)	(-0.452885299)	(-0.428430313)	(-0.144246)	(-0.323017340)	(-0.264343875)	(-0.022242536)
	0.00000000***	0.14050291	0.00000000***	0.00000000***	0.00000000***	0.00000000***	0.00000000***	0.00000000***
$\alpha_{2,1}$	**(2.400173)**	**(0.838961721)**	**(2.550117657)**	**(5.114567261)**	**(3.894208)**	**(3.780508237)**	**6.522721173)**	**(4.657193488)**
	0.00000000***	**0.00056712*****	**0.00000000*****	**0.00000000*****	**0.00000000*****	**0.00000000*****	**0.00000000*****	**0.00000000*****
$\beta_{1,2}$	(-0.006642)	(-0.187096122)	(-0.075075329)	(-0.055198048)	(-0.003750)	(0.022203886)	(0.012380458)	(0.041809063)
	0.00000000***	0.00022621***	0.00000000***	0.00000000***	0.00000000***	0.00024299***	0.25204329	0.00000019***
$\beta_{2,1}$	**(0.529698)**	(0.344380352)	**(0.423503370)**	**(0.626387100)**	**(0.894262)**	(-0.000035945)	**(1.397264296)**	**(0.866032057)**
	0.00000000***	0.36964152	**0.00000000*****	**0.00000000*****	**0.00000000*****	0.98698921	**0.00001365*****	**0.00000000*****

Note(s): ***, **, * statistical significance at 1%, 5 and 10% levels, respectively

During the subprime mortgage crisis, oil prices and stock markets in oil-exporting countries such as Japan, Mexico, Russia, South Korea, the United States, Turkey, and South Africa were closely linked. This meant that changes in one market often led to changes in the other. The strength of a country's economy influenced how this link worked. Sometimes, a rise in oil prices led to a fall in stock prices, and vice versa. However, the overall impact was similar across all countries during this period.

Several factors contributed to this close relationship. The real estate boom in the early 2000s created a positive atmosphere for global markets, including oil and stocks. This led to higher prices in both areas. In addition, events such as the September 11 attacks and the Iraq War sparked uncertainty across economies, leading to similar movements in stock markets and a closer link with oil prices. Finally, China's rapid economic growth and its impact on global trade created a sense of optimism in stock markets around the world, regardless of the country's origin. During the subprime mortgage crisis, oil prices and stock markets generally moved in opposite directions for most oil-exporting countries. The only exception was the United Kingdom.

The global financial crisis of 2008-2009 had a similar impact on all stock markets, causing them to move in tandem. During this period, oil prices and stock markets generally moved in opposite directions, with both average prices and price fluctuations being negatively affected. The crisis was triggered by the massive issuance of risky US mortgages, which led to a global financial shock. This shock can be considered an oil shock because it reduced global demand for oil. Following the subprime mortgage crisis, the European sovereign debt crisis had a further impact on both the oil and stock markets. This crisis affected many European countries and resulted in a significant link between oil prices and stock markets for most countries.

This study investigated how oil price changes affect stock market volatility before and during the COVID-19 pandemic. The results show that oil price volatility and stock market volatility are strongly linked, and that this link is even stronger during the pandemic. This means that oil price changes have a greater impact on stock markets during the pandemic.

The study found that the relationship between oil price volatility and stock market volatility is stronger during the pandemic than before. This suggests that the COVID-19 outbreak has made global financial markets more interconnected and vulnerable to shocks. Other studies have also shown that the pandemic has increased the risk of financial contagion, meaning that problems in one market can quickly spread to others. This research aligns with previous studies that have found a link between changes in the oil market and emerging stock markets.

Overall, our results show that oil price volatility has a direct impact on stock market returns in many countries. The influence generally flows from oil to stocks, not vice versa. However, there are differences between countries, likely due to the diverse economic situations in emerging markets. It is important to remember that this research was conducted during a period of significant financial instability. This means that the impact of oil on stock markets may have been stronger than usual due to the general uncertainty and volatility in the global economy.

During the first period, the relationship between oil prices and stock market returns in exporting countries showed clear variations. Russia, for example, displayed a high positive coefficient of 0.1181, indicating that rising oil prices positively influenced its stock market performance, reflecting the country's heavy reliance on oil exports for its economic growth. South Korea and the United Kingdom also displayed positive coefficients (0.6076 and 0.6229, respectively), suggesting that these economies benefited from rising oil prices, likely due to strong demand and favorable economic conditions. Conversely, Japan's negative coefficient of -0.0786 indicates a more complex scenario, in which rising oil prices did not translate into positive stock market performance, perhaps due to its status as a major oil importer and the associated costs that impacted its economic outlook.

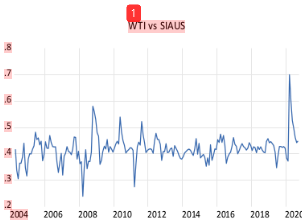
The onset of the subprime crisis marked a significant shift in the dynamics of oil prices and stock market returns for oil-exporting countries. Russia's $\alpha_{1.2}$ coefficient climbed to 1.9059, illustrating that despite global financial turmoil, the stock market maintained a strong correlation with oil prices, likely due to the country's vast oil reserves. Conversely, Japan's coefficient became significantly positive, at 0.7369, indicating a new sensitivity to oil prices, which could reflect changes in investor sentiment during the crisis. The significant negative coefficients for South Africa and Turkey (-0.4828 and -0.2557, respectively) suggest that these countries faced heightened economic uncertainty, where lower oil prices did not provide the expected relief, reflecting broader economic fears and reduced demand.

Then in the third period, the recovery phase following the subprime crisis, the coefficients for exporting countries displayed a mix of resilience and persistent difficulties. Russia maintained a positive $\alpha_{1.2}$ coefficient of 0.1292, indicating that oil price increases continued to support stock market performance as the global economy stabilized. Mexico displayed a small positive coefficient of 0.0042**, suggesting that while oil prices had some influence, the relationship was not as strong as in previous years. South Korea's coefficient of 0.5363 indicates a favorable response to oil price increases, reflecting confidence in growth. However, the mixed results across countries imply that while some markets are stabilizing, others, particularly Turkey, continue to show vulnerability to external shocks.

Next period highlighted a shift toward more pronounced volatility in response to oil price changes. Japan's negative coefficient of -0.3335 indicates increasing sensitivity to falling oil prices, perhaps due to economic stagnation and rising costs. In contrast, Mexico's coefficient remained stable, close to zero, suggesting less sensitivity to oil price changes. The United Kingdom and South Africa displayed positive coefficients (0.5429 and 0.0353**, respectively), indicating that their stock markets continued to react favorably to rising oil prices, reflecting some resilience in economic conditions. However, the volatility in the Turkish market suggests ongoing concerns about economic stability amid fluctuating oil prices.

Finally, The COVID-19 pandemic and geopolitical tensions had a significant impact on exporting countries, leading to unprecedented volatility. Japan's coefficient remained negative (-0.2238), indicating continued difficulties amid falling oil prices. Mexico displayed a strong positive response (0.0000***), reflecting coping strategies in its oil-dependent economy. The substantial $\alpha_{2.1}$ value for Russia (2.4002) suggests that past oil shocks have had a lasting impact on its market behavior, highlighting the interconnectedness of oil prices and stock market performance during crises. The United States displayed significant negative coefficients in all cases, indicating severe spillovers from falling oil prices. Overall, this period underscores the critical role of oil prices in stock market dynamics, especially during global disruptions.

Analysis of these periods reveals the complex relationship between oil prices and stock market performance in exporting countries. Under stable economic conditions, rising oil prices typically boost stock market returns, signaling confidence in growth and increased income for oil-dependent economies. However, during times of crisis, this relationship often reverses, with falling oil prices correlated with lower stock market performance, reflecting broader economic fears and reduced demand. The lingering effects of past shocks illustrate how historical events influence investor sentiment, highlighting the need for markets to adapt to changing economic landscapes. Overall, the results indicate that while some exporting countries benefit from rising oil prices, others are vulnerable to the negative effects of price declines, particularly during periods of economic instability, highlighting the critical interaction between energy markets and broader economic conditions



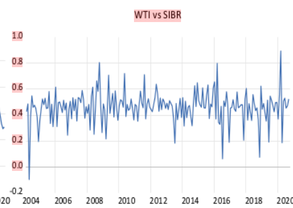


Figure 1: Dynamic Conditional Correlation between Oil Price and Stock Returns of Importing Countries

Figure 2: Dynamic Conditional Correlation between oil price and stock market returns for oil exporting countries

We studied the joint evolution of the oil price (WTI oil index) and the stock market of the G20 countries between 2004 and 2024. This period includes several major crises, such as the 2008 financial crisis, the European debt crisis, the COVID-19 pandemic, and, more recently, Russia's invasion of Ukraine. We analyzed 16 G20 countries for which data were available, focusing on 8 oil-exporting and 8 oil-importing countries. To do this, we used a statistical model called DCC-GARCH (1,1) to understand how the relationship between oil prices and stock markets has evolved over time. This model is particularly useful because it allows for both volatility (the magnitude of price changes) and correlation (the magnitude of simultaneous changes) to vary over time.

Our results clearly demonstrate the impact of major crises on oil-exporting and oil-importing countries. We can observe how these events affected the relationship between oil prices and stock markets. The 2008-2009 financial crisis was a major event that shook the world. It began with problems in the real estate market in 2006, when many people were unable to repay their mortgages. This situation spread throughout the financial system, causing a global crisis. One of the main consequences was the fall in oil and natural gas prices, with the price of a barrel of oil falling from $133.88 to $39.09, and the price of natural gas from $12.69 to $4.52. Looking back at the period when the real estate crisis peaked in 2007, some interesting findings emerge. For oil-importing countries, the drop in prices was good news, allowing them to buy oil more cheaply, which benefited their businesses and stock markets.

On the other hand, oil-exporting countries suffered from this price decline, earning less money from selling oil, which had a negative impact on their stock markets. Market movements are interconnected, and their relationships evolve over time. During crises, such as the European sovereign debt crisis in 2010, markets tend to converge. This was also observed during the Latin American debt crisis of the 1980s, which had a lasting negative impact on the region.

The current situation in Europe is worrying because it shares similarities with past crises. Russia's invasion of Ukraine in 2022 exacerbated tensions in energy markets, leading to increased volatility in oil prices. This geopolitical crisis has caused a sharp increase in oil prices, with barrels reaching historic highs, impacting the economies of both importing and exporting countries. Countries that rely heavily on exports could face a high risk of default if oil prices fall. Indeed, falling oil prices often lead to rising interest rates, complicating the management of these countries' finances.

During the European sovereign debt crisis (2010-2016), the spread between government bond interest rates across European countries widened significantly, coinciding with major events in the Middle East and a sharp drop in oil prices (nearly 75%) between 2014 and 2015. After controlling for economic factors, our research shows that the widening of these interest rate spreads was strongly linked to increased demand for safe assets due to instability in the Middle East and North Africa (MENA) region. The collapse in oil prices also led to an increase in demand for safe assets.

The collapse in oil prices also reduced global demand, which negatively impacted interest rate spreads, particularly in peripheral eurozone countries. This is likely because these countries are more sensitive to oil market disruptions. Finally, our results suggest that changes in the supply of goods and services had little impact on interest rate spreads during this period, with the exception of some positive correlations in Belgium and France. The Arab Spring had a significant impact on oil prices, prompting people to buy more oil than usual—a so-called "precautionary demand shock"—due to concerns about future supply disruptions. Simultaneously, oil production problems in the region also led to supply shocks. Interestingly, only Belgium and France saw their bond prices move in response to these supply shocks, likely due to their close trade relationships with oil-producing countries in the Arab world. When oil prices fell between 2014 and 2015, it was mainly due to a combination of factors: a decline in demand (aggregate demand shock) and oil production problems (supply shock).

During this period, bond prices did not change much in response to the precautionary demand shock, but they moved as expected when oil prices fell due to the decline in demand. The fact that bond prices did not respond much to supply shocks during this period suggests that these shocks were not very significant for financial markets.

This study examined the relationship between crude oil prices and stock market prices before and during the COVID-19 pandemic. Using a technique called cross-wavelet transform, we found that oil prices and stock prices move together, especially in the short term (high frequency). This means that when oil prices rise, stock prices tend to rise as well, and vice versa. However, the study also found that this relationship was weaker in the long term (low frequency) during the pandemic. This suggests that the short-term link between oil and stock markets became more important during the crisis.

Another study by Salisu et al. (2020) showed that oil prices influenced stock prices before the pandemic, but after the pandemic, the relationship became bidirectional. This means that oil prices and stock prices influence each other. The study also noted that oil prices were more volatile than stock prices before and during the pandemic. However, all stock markets posted positive returns, even during the crisis, and these returns were actually higher during the pandemic.

Table: Results of the volatility transmission between oil prices and stock index using DECO-GARCH model total period

	SIAUS	SIBR	SICA	SICH	SIFR	SIGER	SIIND	SIITA
Univariate GARCH model								
Constant	(0.002084) 0.0387	(0.002022) 0.0009	(0.003344) 0.0119	(0.002066) 0.0177	(0.002004) 0.0121	(0.002491) 0.0224	(0.001926) 0.0334	(0.002869) 0.0063
ARCH	(0.429225) 0.0013	(0.431508) 0.0094	(0.460592) 0.0045	(0.413184) 0.0008	(0.409595) 0.0007	(0.404678) 0.0014	(0.441761) 0.0026	(0.381733) 0.0022
GARCH	(0.324816) 0.0893	(0.305286) 0.0089	(0.189755) 0.3059	(0.357272) 0.0107	(0.371357) 0.0022	(0.31840) 0.0501	(0.359363) 0.0211	(0.288627) 0.0503
DECO model								
ADECO	(0.030234) 0.5337	(0.165718) 0.6844	(0.0000002) 0.6247	(0.153268) 0.0057	(0.014628) 0.4806	(0.0000005) 0.9519	(0.096540) 0.9358	(0.009775) 0.5628
BDECO	(0.157176) 0.4999	(0.000000) 1.0000	(0.893682) 0.0012	(0.507650) 0.0030	(0.935592) 0.0000	(0.781840) 0.9446	(0.000000) 1.0000	(0.954203) 0.0000
Multivariate diagnostic tests								
Normality test	35.983 (0.0000)**	29.368 (0.0000)**	104.41 (0.0000)**	40.467 (0.0000)**	78.476 (0.0000)**	36.900 (0.0000)**	71.330 (0.0000)**	63.401 (0.0000)**
Hosking(10)	44.2050 (0.2260512)	27.1750 (0.9041617)	29.3978 (0.8400822)	78.8700 (0.0001105)	25.3536 (0.9422108)	36.1182 (0.5567155)	32.4837 (0.7219817)	23.2701 (0.9710833)
Li-McLeod(10)	44.3532 (0.2214646)	27.5854 (0.8937959)	30.0286 (0.8184610)	78.4137 (0.0001256)	26.0490 (0.9291889)	36.4738 (0.5400842)	33.1051 (0.6950343)	24.0035 (0.9625389)

Hosking (10) and McLeod-Li (10) multivariate Portmanteau statistics test the null hypothesis of no serial correlation in squared standardized residuals (10 lags). P-values are shown in brackets. ***,**,* represent 1%, 5%, and 10% significance level, respectively

	SIJAP	SIMEX	SIRUS	SISAF	SISKOR	SITUR	SIUKING	SIUSA
Univariate GARCH model								
Constant	(0.002417) 0.0027	(0.003531) 0.0000	(0.002643) 0.0001	(0.002778) 0.0184	(0.003113) 0.0177	(0.002150) 0.0036	(0.001830) 0.0172	(0.002780) 0.0261
ARCH	(0.435892) 0.0009	(0.531491) 0.0012	(0.515061) 0.0015	(0.495264) 0.0039	(0.392488) 0.0031	(0.426267) 0.0014	(0.436128) 0.0043	(0.492119) 0.0067
GARCH	(0.288043) 0.0196	(0.016514) 0.8217	(0.187375) 0.0703	(0.187187) 0.3607	(0.253684) 0.1915	(0.334861) 0.0038	(0.364646) 0.0140	(0.457126) 0.0156
DECO model								
ADECO	(0.010848) 0.6638**	(0.024853) 0.2488**	(0.0000004) 0.7624*	(0.0000001) 0.9965*	(0.0000002) 0.9930*	(0.0000005) 0.5671*	(0.0000002) 0.4490**	(0.010067) 0.6526*
BDECO	(0.895304) 0.0000***	(0.923706) 0.0000***	(0.902314) 0.0036***	(0.843700) 0.8933*	(0.853494) 0.8080*	(0.824332) 0.1012**	(0.867917) 0.0001***	(0.945065) 0.0000***
Multivariate diagnostic tests								
Normality test	25.582 (0.0000)**	37.101 (0.0000)**	49.837 (0.0000)**	58.998 (0.0000)**	40.530 (0.0000)**	30.398 (0.0000)**	72.326 (0.0000)**	90.426 (0.0000)**
Hosking(10)	25.6528 (0.9368307)	34.6209 (0.6264966)	52.5773 (0.0581337)	40.1207 (0.3763424)	29.9395 (0.8216008)	26.9725 (0.9090297)	29.0755 (0.8505622)	33.4448 (0.6799757)
Li-McLeod(10)	26.1565 (0.9270126)	34.9986 (0.6090006)	51.8696 (0.0661787)	40.5893 (0.3569344)	30.4501 (0.8032269)	27.3081 (0.9008730)	29.4885 (0.8370604)	34.0581 (0.6523149)

Hosking (10) and McLeod-Li (10) multivariate Portmanteau statistics test the null hypothesis of no serial correlation in squared standardized residuals (10 lags). P-values are shown in brackets. ***,**,* represent 1%, 5%, and 10% significance level, respectively

The SIAUS index has a constant of 0.002 and ARCH and GARCH coefficients of 0.429 and 0.324, respectively; this indicates a rather moderate sensitivity to past volatility shocks, implying a significant effect on the volatility of this index by oil price fluctuations. The reaction is considerable, but it is also moderately resilient, reflecting the long-term stability of the index in the face of oil price changes.

In the case of the SIBR index, the constant is also 0.002, while the ARCH and GARCH coefficients are 0.431 and 0.305. This combination suggests that any volatility shock may not directly affect the index; there may be other factors that somehow counteract day-to-day movements in oil prices. These factors could include widespread diversification of the income structure or some stabilizing effects of the economy against oil price volatility, which gives this index stable performance in a context of uncertainty.

The SICA index displays a constant of 0.003 and is more reactive in terms of volatility with an AARCH of 0.460 and a GARCH of 0.189. This should therefore mean that SICA's reactions to oil price changes are more pronounced, which could be a key element for investors. The risk of being an index of stronger co-movement with oil market fluctuations has created a clear need to understand investment in this index.

A constant of 0.002 and coefficients ARCH (0.413) and GARCH (0.357) indicate a moderate sensitivity of the SICH index to the volatility of oil price changes. This means that even if oil price changes have some influence on the index, it has enough resilience to withstand extreme shocks, which is indicative of an essentially balanced economy.

The SIFR index shows a constant of 0.002, an ARCH of 0.409, and a GARCH of 0.371. This once again demonstrates a strong reactivity to past violence, making it an index that has strongly felt the effects of oil price fluctuations. Investors should monitor it closely, as it could massively alter the landscape.

These indices have very different ARCH-GARCH coefficient pairs. The IGER index (0.441, 0.359) suggests that it is highly sensitive to oil price volatility, indicating that it is highly vulnerable to market fluctuations. In contrast, the IIND index (0.381, 0.288) exhibits a more moderate response that could suggest some degree of protection against oil market fluctuations. The IITA results also indicate varying levels of sensitivity, reflecting the diversity of the economic sectors they represent.

The SIJAP index had a constant of 0.000 and an ARCH factor of 0.43, showing significant volatility potential due to its heavy reliance on energy markets. The implication of such high sensitivity means that changes in the price of oil would put substantial pressure on the performance of this index.

The SIMEX index is relatively insensitive to any changes in the price of oil, given its ARTCH and GARCH coefficients of 0.53 and 0.01. This may indicate that it is highly diversified and has little dependence on the energy sector, which could be beneficial in a volatile market environment.

SIRUS exhibits moderate sensitivity to oil price shocks with an index of 0.51 and 0.18, indicating a kind of balanced economic structure capable of absorbing volatility-induced shocks, probably because this index is supported by somewhat diversified assets.

These indices exhibit ARCH coefficients of 0.495 and 0.392, indicating some vulnerability to volatility shocks. The similarities end there; beyond that, these indices exhibit varying levels of resilience, which would be important for any market participant seeking a stable investment in an uncertain economic environment.

Finally, SITUR, SIUKING, and SIUSA respond very differently to oil price fluctuations, with their ARCH coefficients ranging from 0.45 to 0.49. This shows sensitivity to volatility, which also indicates a certain level of adaptability to external shocks that remain important in helping market stability.

Overall, the results highlight the complex relationships between oil prices and the analyzed indices. The level of sensitivity and resilience varies among these indices, illustrating the need to appreciate this dynamic for investors navigating a volatile economic landscape. The analysis itself suggests that while some indices are more intimately affected by changes in oil prices, others appear able to withstand such shocks, resulting in different opportunities and risks for almost all.

6. CONCLUSION

Indeed, over the past ten years, this research has clearly demystified the interrelationship between oil price changes and stock market performance in the G20 economies. Through the use of sophisticated econometric tools, particularly the DECO-GARCH framework and univariate GARCH models, the nuances of volatility transmission between the two main financial domains have been captured. The results of this work have shown that very significant events on the global scene, including the COVID pandemic, have actually made a difference in the value of oil prices, as well as stock market indices.

Thus, it became evident that oil price volatility increased in the early days of the pandemic; however, it decreased significantly when stock markets subsequently behaved in response to other external determinants. This shows that the market response to external shocks is constantly evolving, requiring investors to be vigilant and adapt.

We found varying degrees of sensitivity and resilience in equity market indices, with indices such as SICA and SIFR showing radical movements in response to oil price changes, illustrating low immunity, while others showed remarkable resilience, perhaps due to their divergent economic structures. This adds to the complexity of the different effects that oil price volatility can have on financial markets.

Overall, this effort makes a significant contribution to the existing literature by detailing and contextualizing how oil markets alter stock market trajectories during times of economic uncertainty. The DECO-GARCH model has proven invaluable in capturing the time-varying correlations and asymmetries affected in these types of financial interactions.

As global economies face energy market transitions and geopolitical disruptions, this research is highly relevant and offers insights for investors and policymakers. Understanding oil price volatility and its effects on stock markets is essential for making sound investment decisions and developing strategies to improve economic resilience. This work could be extended in the future by adding additional variables to the relationship, further enriching our knowledge of the holistic interrelationship of global financial markets. In our study, we found skewness and a compound t-distribution, known as kurtosis, in both oil and stock prices. We then checked oil price changes for 16 G20 countries over five smaller intervals during the study period and distinguished between oil exporters and importers to understand how oil price volatility affects the economies of major oil producers and consumers differently.

In summary, the relationship between oil prices and stock returns is, at best, fluid and dynamic over time. There is strong evidence to support the argument that oil prices "directly" transmit volatility to stock returns. Typically, shocks and volatility flow from oil markets to stock markets, with cross-country differences reflecting this inherent diversity. This complexity is crucial for investors hoping to navigate the uncertain seas of the global financial crisis.

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