Sosyoekonomi

2023, Vol. 31(56), 217-240

RESEARCH ARTICLE

ISSN: 1305-5577
DOI: 10.17233/sosyoekonomi.2023.02.11
Date Submitted: 10.11.2022
Date Revised: 13.03.2023
Date Accepted: 14.04.2023

The Effects of Oil Price Shocks on Clean Energy and Oil and Gas Stock Returns

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Petrol Fiyat Şoklarının Temiz Enerji ile Petrol ve Gaz Şirketlerinin Hisse Senedi Getirilerine Etkileri

Abstract

This study empirically examines how fluctuations in oil prices affect the stock returns of clean energy and oil and gas companies between 2001:01 and 2022:06. Our results show that a negative oil supply shock affects the stock returns of clean energy companies positively. In contrast, an oil-specific demand shock negatively affects them. The findings also reveal that an increase in oil prices owing to an oil-specific demand shock tends not to improve the stock returns of oil and gas companies. Consequently, the results indicate that oil and clean energy are not alternatives.

Keywords : Oil Price Shocks, Substitution Effect, Clean Energy Stock Returns, Oil and Gas Stock Returns, The Structural VAR.

JEL Classification Codes : C58, Q31, Q42.

Öz

Bu çalışma, 2001:01 ile 2022:06 yılları arasında petrol fiyatlarındaki dalgalanmaların temiz enerji ile petrol ve gaz şirketlerinin hisse senedi getirilerini nasıl etkilediğini ampirik olarak incelemektedir. Bu çalışmada bulunan sonuçlar, negatif bir petrol arz şokunun temiz enerji şirketlerinin hisse senedi getirilerini pozitif yönde etkilediğini, petrole özgü bir talep şokunun ise negatif yönde etkilediğini göstermektedir. Bulgular ayrıca, petrole özgü talep şoku nedeniyle oluşan petrol fiyatlarındaki artışın, petrol ve gaz şirketlerinin hisse senedi getirisini artırma eğiliminde olmadığını ortaya koymaktadır. Bu nedenle sonuçlar, petrol ve temiz enerjinin birbirinin alternatifi olmadığını göstermektedir.

Anahtar Sözcükler : Petrol Fiyat Şokları, İkame Etkisi, Temiz Enerji Hisse Senedi Getirileri, Petrol ve Gaz Hisse Senedi Getirileri, Yapısal VAR.

1. Introduction

According to Yergin (1991: 12), oil symbolises human progress. Oil is unquestionably a necessary component of modern production. Furthermore, oil is seen not only as an input for production but also as a financial asset and a barometer of global economic activity (Venditti & Veronese, 2020: 1). Changes in oil prices have an impact on companies' investment decisions since they have a direct impact on production costs (Aziz & Bakar, 2013: 109). Several geopolitical, economic, and other developments have impacted crude oil prices, including war, OPEC decisions, and the financial crisis. To understand oil price shocks, it is crucial to identify the factors that influence price fluctuations.

83% of the world's energy consumption comes from fossil fuels, making fossil fuels the primary energy source for modern economies (BP, 2021). Oil is one of the fossil fuels, which raises the worry that it contributes to greenhouse gas emissions. For instance, oil accounted for 46% of all US energy-related CO_2 emissions in 2021 (EIA, 2022). Combating climate change is one of the most important challenges globally since carbon emissions are constantly rising. Instead of lowering energy demand, switching to clean energy is the best way to reduce CO2 emissions. The growing number of nations attempting to achieve net-zero emissions by 2050 was noted in the IEA's Net Zero Emissions by 2050 Scenarios (2021a: 3). Global emissions of greenhouse gases are also rising, however. It is further noted that this gap between words and action must be closed. The transition to clean energy is heavily emphasised in this direction. Globally, the capacity of renewable energy increased by more than 260 gigawatts (GW) in 2020.

Furthermore, renewable energy sources accounted for nearly 80% of the world's total new power generation capacity in 2020, showing that renewables are becoming the preferred source of new electricity generation in the world (IRENA, 2021: 3). As a result, the generation of renewable energy sources, including hydroelectricity, climbed by over 6% in 2020, boosting their share of the world's electricity generation mix to over 28%. Due to ongoing cost reductions in solar and wind technology and the aggressive and effective climate regulations adopted by the EU, US, China, India, Japan, Chile, and Australia, solar and wind energy production has steadily increased (Enerdata, 2022). Furthermore, the IPCC's scenarios (2018: 15) predict that by 2050, 70 to 85% of all electricity will come from renewable sources. On the other side, Lin et al. (2022: 1) claims that as of July 28, 2022, humanity had used up all biological resources that could regenerate themselves in a year and that the demand outweighed the supply. As of 2021, the share of renewable energy (including hydropower) in the world's primary energy consumption was 13,47% as opposed to the proportions of oil and gas consumption, roughly 31% and 24,5%, respectively (BP, 2022). Oil is the most widely used primary energy source in global energy consumption.

On the other hand, the increase in demand and supply for clean energy sources is driven by the rise in oil prices. Simply put, unanticipated changes in oil prices lead to market uncertainty, which raises the need for an energy substitution between oil and clean energy (Zhao, 2020: 1). Moreover, due to the worldwide pressure created by climate change and carbon emissions, brown (dirty) companies tend to switch to clean energy (Urom et al., 2022: 326). Thus, it is crucial to investigate whether shocks to the oil market and aggregate demand cause substitution effects for clean energies. Clean energy sources are now among the most competitive energy sources due to recent rapid technology advancements and falling costs. This study aims to clarify the two key questions in this regard. Does the financial performance of clean energy companies respond to crude oil price shocks? Are these responses due to the driving force of the shock in the crude oil market? In this context, we first investigate how a shock to the oil supply impacts the financial performance of clean energy companies. Unpredictable global oil production changes are linked to oil supply shocks. Studies have shown that the effects of oil supply shocks on financial markets are either negative or limited (see, for example, Kilian & Park, 2009: 1286; Ready, 2018: 157; Mokni, 2020: 605; Demirer et al., 2020: 6; Zhu et al., 2021: 7; Kielmann et al., 2022: 1563). The negative impact is understandable, given that a shock to the oil supply would increase oil prices, lead to a fall in economic activity, and negatively influence stock returns. Because an increase in oil prices will put pressure on companies' production costs, lower households' discretionary income and spending, and boost inflationary expectations (Demirer et al., 2020: 6). Because of this, it is anticipated that the demand for renewable energies would rise as oil prices rise. Renewable energy sources were formerly uneconomical substitutes for fossil fuels since they were less efficient and more expensive. Yet, by offering government subsidies and incentives to consumers and producers that choose renewable energy, renewable energy has transitioned from an uneconomical option to an economic one (Ross, 2022). As clean energy may replace oil economically, it's possible that in response to high oil prices, oil companies could move to renewable energy, raising the demand for renewable energy. In this way, the market for renewable energy may grow, and clean energy companies' financial performance could improve.

Second, we explore how an aggregate demand shock affects the financial performance of clean energy companies. The developments in global oil demand associated with global business cycles, such as the financial crisis, are captured by aggregate demand shock. According to the previous studies (Kilian & Park, 2009: 1274; Filis et al., 2011: 152; Ready, 2018: 17; Mokni, 2020: 605; Demirer et al., 2020: 6; Hasanov & Dagher, 2021: 18), an aggregate demand shock has positive effects on financial markets since it leads to an increase in economic activity. Economic activity will grow in response to a positive aggregate demand shock, and improvements in economic activity will favourably impact the stock returns of clean energy companies because it is believed that a period of economic prosperity will make the switch to environmentally friendly energy easier. The rise in economic activity is expected to affect the financial performance of clean energy companies positively. Economic prosperity is one of the best times to switch to renewable energy sources.

Last but not least, we reveal how an oil-specific demand shock affects the financial performance of clean energy companies. Oil-specific demand shocks are associated with unpredictability in oil price fluctuations due to rising concerns about future oil supply shortages (Kilian & Park, 2009: 1270). Oil-specific demand shocks are intended to reflect the factors affecting oil prices after adjusting for oil supply and global demand shocks, that is due to the relationship between precautionary demand and the availability of future crude oil supply (Davig et al., 2015: 24). For instance, when there is growing uncertainty about future oil supply, there is a tendency for precautionary demand to surge, which causes an abrupt increase in oil prices (Alquist & Kilian, 2010: 539). Hence it is anticipated that oil-specific demand shocks will have a detrimental impact on the stock returns of clean energy companies. Presently, rapidly expanding oil demand, particularly in emerging market economies such as China and India, supports growing concerns about shortfalls in predicted oil supply (Zhao, 2020: 8). Hence, it may be claimed that the current oil demand may increase if a future decline in the supply of oil is anticipated. This also indicates that oil producers must transition to renewable energy sources. Therefore, the stocks of oil-related companies will benefit if there is no substitution effect in this type of oil shock. In contrast, the reserves of renewable energy companies will deliver diminishing returns.

In the previous literature, studies on the effects of oil price shocks are mainly focused on the interaction between oil price shocks and macroeconomic aggregates (see, for example, Hamilton, 1983; Kilian & Vigfusson, 2011; Abiyev et al., 2015; Charfeddine & Barkat, 2020; Kocaarslan et al., 2020) and oil price shocks and stock markets (see, Park & Ratti, 2008; Cunado & Perez de Gracia, 2014; Hashmi et al., 2021; Jiang & Liu, 2021, amongst others). Only a small number of studies, however, have looked at how different oil price shocks impact the stock prices of clean energy companies (Henriques & Sadorsky, 2008; Managi & Okimoto, 2013; Inchauspe et al., 2015; Pham, 2019; Zhang et al., 2020; Zhou & Geng, 2021, amongst others).

This paper contributes to the literature in the following ways. First, we examine the effects of different oil price shocks on clean energy stock returns. It is well acknowledged that changes in oil prices play a key role in advancing clean energy. As oil can influence all markets in various ways and maintains its leading position in global energy consumption, it is critical to determine whether oil price changes impact clean energy, which has a rapidly growing market and is crucial in combating climate change. Second, we utilise the Global Economic Conditions (GECON) indicator, newly established by Baumeister, Korobilis & Lee in 2020, to quantify the effects of global economic demand shocks on the financial performance of clean energy firms, in contrast to the previous studies. In the debate that arose in 2019 between Kilian and Hamilton on the measures of global real economic activity, Hamilton (2019: 301) stresses that the Kilian index has failed to explain the changes in global movement over the past decade and that global economic activity is more volatile than it seems.

Furthermore, Baumeister and Guérin (2020: 3) discover that the GECON index is a more effective indicator than the Kilian index for measuring the timing and magnitude of fluctuations in the global business cycle. Baumeister et al. (2020: 16-19) further say that the GECON index is a more comprehensive index than previous indices since it is constructed by applying the expectation-maximization algorithm to sixteen indicators[1] and does not attempt to capture merely the cyclical component of global real economic activity. The GECON index can therefore monitor energy price volatility more reliably than other proxies of economic activity because it is associated with different indicators (Salisu et al., 2021: 144). In light of this, the GECON index is utilised in this study. The last contribution of this article is a comparison of the effects of oil price shocks on the stock returns of oil and gas and clean energy companies. The transition to clean energy and efforts to reduce reliance on fossil fuels is becoming increasingly important. To live better in an industrialised world, we are in a new era where these essential energy sources must be replaced with clean energy sources. To highlight the substitution effect, we evaluate how fluctuations in oil prices affect the stock returns of clean energy and oil and gas companies.

The main findings are as follows. First, both models using the ECO and NEX indices show that a negative oil supply shock positively impacts clean energy stock returns. Second, in the model using the ECO index, increases in aggregate demand have an immediate positive impact on the stock returns of clean energy companies. Third, in both models, the stock returns of clean energy are negatively impacted by an oil-specific demand shock. This means that increased oil prices driven by oil-specific demand shocks do not induce investors to move to clean energy sources. Lastly, to clarify the substitution effect, when the impact of oil price shocks on clean energy and oil and gas stock returns are compared, it is observed that the increase in oil prices owing to the oil-specific demand shock does not tend to improve oil and gas stock returns. Consequently, previous findings imply that oil and clean energy are separate from one another.

The remaining sections of the paper are as follows. The literature review on the link between oil price shocks and the stock returns of clean energy companies is presented in Section 2. The datasets are described in Section 3. The empirical methodology and the findings are presented in Sections 4 and 5. The stock returns of oil and gas and clean energy companies are compared in Section 6. Conclusions and policy repercussions are included in Section 7.

2. Literature

Most prior studies studying the relationship between oil prices and macroeconomic aggregates have established a consensus on the asymmetric responses of macroeconomic variables to oil price shocks: Rises and declines in oil prices have asymmetric effects on aggregate economic activity (Balke et al., 2002: 27; Kilian & Vigfusson, 2011: 419; Charfeddine & Barkat, 2020: 13; Kocaarslan et al., 2020: 5). Also, scholars looking into how changes in the price of oil affect financial markets primarily contend that both positive and negative changes in the price of crude oil have asymmetric effects on stock prices (see, Hashmi et al., 2021: 7; Jiang & Liu, 2021: 1, amongst others). Yet, few researchers have

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[1] *It is related to "commodity prices, economic activity, financial indicators, transportation, uncertainty and expectation measures, weather, and energy-related indicators" (Baumeister et al., 2020: 16-19).*

explored the relationship between the stock returns of clean energy companies and oil price shocks. Understanding the growth of the clean energy sector requires revealing the link between oil price shocks and stock returns of clean energy companies. It has been noted that improvements in the financial performance of clean energy companies have occurred due to higher oil prices (Henriques & Sadorsky, 2008: 998).

Henriques & Sadorsky (2008: 1009) analyse whether the stock returns of clean energy companies are responsive to changes in oil prices and conclude that oil price shocks have little effect on the stock returns of clean energy companies. Managi & Okimoto (2013: 8) create a model employing the same variables as Henriques & Sadorsky (2008) by utilising Markov-switching vector autoregressive models. In contrast to Henriques & Sadorsky (2008), they discover a positive effect of oil price shocks on clean energy stock returns. Inchauspe et al. (2015: 325) use a state-space multi-factor asset pricing model to analyse the relationship between oil prices and stock market returns by employing the NEX as the clean energy index, in contrast to previous studies. This study suggests that the MSCI World Index and technology stock returns significantly correlate with NEX returns, whereas oil prices are not as high. Pham (2019: 355) examines the connection between oil prices and clean energy stocks by considering sub-sectors in the clean energy stock market and demonstrates how this connection has altered dramatically over time in various sub-sectors.

More recently, Zhao (2020: 15-16) used the structural VAR model of Kilian (2009) to find that oil supply shocks and aggregate demand shocks positively affect clean energy stock returns, while policy uncertainty and oil-specific demand shocks have adverse effects. He also discovers that the first seven months of an oil-specific demand shock's positive effect on oil and gas stock returns are followed by a negative effect. Zhang et al. (2020: 1) study how oil price shocks affect the clean energy stock market and find that the impact is asymmetric at higher quantiles of oil shocks over the long term. In addition, the effect of aggregate demand shocks on clean energy stocks over the medium term is favourable at both the lower and higher quantiles. By substituting a risk shock for an oil-specific demand shock, Zhou & Geng (2021: 1-6) examine the connection between oil price shocks and emerging energy stock markets in China, Europe, and the US. They discover that in contrast to the oil supply shock, which has little impact, oil demand and risk shocks have more significant explanatory power on the returns of all new energy stock markets. In addition, the effects of supply and demand shocks on the volatility of all new energy stock markets are minimal. On the other hand, the risk shock significantly affects how volatile the new energy stock markets are in China and the US.

Maghyereh & Abdoh (2021: 12) extend the research of Zhang et al. (2020) by incorporating oil and gas stock returns and a quantile cross-spectral technique in addition to SVAR. They discover that the oil-specific demand shock is the shock that has the most effects on stock returns for both clean energy and oil and gas. Across the higher quantiles in all horizons, aggregate demand shock substantially impacts oil and gas stock returns. In contrast, the aggregate demand shock influences the returns of clean energy stocks over the medium and long-term horizons. Furthermore, oil supply shock significantly impacts oil and gas stock returns more than clean energy stocks. In their investigation of the connection between financial stress, commodity price volatility, including oil and gas, and clean energy stock returns, Fu et al. (2022: 1) discover that the performance of clean energy stocks is highly impacted by rising financial stress indices, oil and gold prices, and both long- and short-term price movements, but natural gas only significantly impacts clean energy stocks over the long term. The effects of oil price shocks and economic policy uncertainty on the stock returns of oil and gas companies are examined by Kang et al. (2017: 349). However, the effects of these indicators on the stock returns of clean energy companies should be considered. They discover that whereas oil-specific demand shock has an immediate positive impact that lasts for virtually the first nine months, aggregate demand shock has a positive impact on the stock returns of oil and gas companies. Diaz & Gracia (2017: 80) find that changes in oil prices have a positive and substantial impact on the real stock returns of oil and gas companies in the short term.

To summarise, there has yet to be a consensus on the consequences of three structural oil price shocks on the stock returns of clean energy companies. As new variables are introduced and the sample period changes, we notice that the impact of shocks varies. We evaluate the financial performance of clean energy companies using the WilderHill clean energy (ECO) index and the WilderHill New Energy Global Innovation (NEX) index. The ECO index, which was the first to track the stock prices of clean energy companies, has emerged as a benchmark index (WilderShares, 2018: 3). Similar to the ECO index, the NEX index consists of companies that prioritise climate change solutions and the usage of clean energy (Solactive, 2022). Also, in contrast to previous studies, we chose the GECON index to measure the overall economic activity.

3. Data

We employ monthly data from 2001:01[2] to 2022:06, a total of 258 observations, for the analysis. These observations cover the recent financial crisis, the Covid pandemic period, and the Russia-Ukraine war. Our data consist of global crude oil supply, the spot price of the refiner's acquisition cost of crude oil (RAC)[3], the consumer price index (CPI) for the US, and the ECO and the NEX indices to measure the stock market performance of clean energy companies and the GECON index developed by Baumeister, Korobilis & Lee in 2020 to measure the global economic activity.

We will use the log differences of world crude oil production in thousand barrels per day to measure the per cent change in global crude oil production. The US CPI will deflate the nominal price of RAC to obtain the real oil price. The real oil prices are expressed in log levels. The GECON index will be used at the level. The ECO and the NEX indices are in

2 *Since the clean energy index is available since 2001, the sample period starts from 2001.*
3 *We also use alternative measures of oil prices as WTI and Brent spot prices. We observe that results are robust to the changes in the oil price measure. Therefore, we do not include these results here but are available from the author on request.*

US dollars. They are designed to identify and monitor the clean energy sector and measure the stock market performance of clean energy companies. The ECO index is a modified, equally weighted index of publicly traded companies in the US that stand to gain from a move toward decarbonisation and cleaner energy (WilderShares, 2018: 3). We also utilise the NEX index in addition to the ECO index. The NEX index also tracks the stock performance of clean energy companies. In contrast to the ECO index, the NEX index concentrates on US and global companies. In addition, the ECO index contains 82 stocks focused on renewable energy technologies, while the NEX index contains 130 stocks (Solactive, 2022). The ECO and the NEX indices are used in log levels. The data are obtained from DataStream (Thomson Reuters), except the GECON index from Baumeister's website.

The historical development of our series across the sample period is depicted in Figure 1. The per cent change in global crude oil production remained steady until Covid-19. The fluctuations of the global economic condition index reveal the global economic cycle. Due to the epidemic caused by Covid-19, containment measures have resulted in a worldwide halt in output and mobility, which has led to a considerable decline in global oil demand. The global pandemic has caused a substantial decrease in oil production and prices, coinciding with a sharp decline in the GECON index.

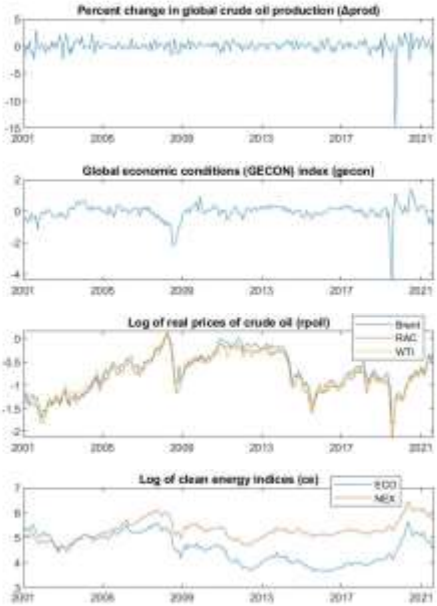
Furthermore, the sharp drops in oil prices came after crises like the 2008 global financial crisis and the Covid-19 pandemic. In 2008, there was a global financial crisis, and by the second quarter of that year, the oil price had reached a record high of $159,87 a barrel. In the second quarter of 2009, oil prices declined to $75,59 due to the post-crisis slowing of the global economy (EIA, 2023). As a result of Covid-19, the slowdown in industrial production and the impact of travel limitations on airline transport have exerted downward pressure on the price of oil. Hence, the most notable decline in oil prices occurred during the corresponding period. One of the OPEC countries, Saudi Arabia, wants to restrict production to stop prices from falling further. Russia, however, prevented this action by boosting its supply and output. Russia retaliated similarly to Saudi Arabia's increase in oil production, which sparked an oil price war[4] (Ma et al., 2021: 3). As a result, the oil price continued to decline. From 2009 to Covid-19, the clean energy indices were relatively steady. Companies lost interest in fossil fuel projects due to the abrupt drops in oil prices and changes in oil supply and demand brought on by Covid-19.

Companies decided to postpone new initiatives and permanently end costly activities in response to the decline in oil prices. Decarbonisation is now at the forefront of companies' recovery agendas thanks to technology advancements and the constantly falling cost of renewable energy. As a result, this circumstance made it easier for nations that produce oil to switch to low-carbon and cleaner energy policies (OECD, 2020: 2-3). That explains why the clean energy indices rose following 2019. From November 2021, however, clean energy indices started to trend downhill, and the Russia-Ukraine war in 2022 only worsened this

[4] *The Russia-Saudi Arabia oil price war in March-April of 2020.*

tendency. As a result of the supply disruption and price hikes caused by Russia's invasion of Ukraine, the countries' goals of lowering their usage of fossil fuels and making a swift transition to renewable energy have shifted. Because the countries' top priority has been finding quick ways to ensure reliable and affordable power. As a result, investments in sustainable energy were delayed (Birol, 2022: 5).

Figure: 1
Historical Evolution of the Series, 2001:01-2022:06



Source: Author’s calculations.

4. The Structural VAR Model

We estimate the SVAR model using monthly data for the vector of time series z_t = ($\Delta prod_t$, $gecon_t$, $rpoil_t$, ce_t), where $\Delta prod_t$ is the per cent change in global crude oil production, $gecon_t$ is the global economic conditions index as a measure for global real economic activity, $rpoil_t$ is a log of the real price of oil, and ce_t denotes log of the clean energy index measuring the stock returns of the clean energy companies.

The SVAR representation is;

$$A_0 z_t = \alpha + \sum_{i=1}^{24} A_i z_{t-i} + \varepsilon_t \quad (1)$$

where ε_t denotes the vector of serially and mutually uncorrelated structural innovations, ε_t = $(\varepsilon_t^{\Delta prod}, \varepsilon_t^{gecon}, \varepsilon_t^{rpoil}, \varepsilon_t^{ce})'$. A_0 and A_i indicate the contemporaneous and lagged coefficient matrices, respectively. Assuming that e_t is the reduced-form error of the corresponding VAR innovations decomposing according to $e_t = A_0^{-1}\varepsilon_t$, where A_0^{-1} has a recursive structure.

The structural model of the form is;

$$e_t \equiv \begin{pmatrix} e_{1t}^{\Delta global\ oil\ production} \\ e_{2t}^{global\ real\ activity} \\ e_{3t}^{real\ price\ of\ oil} \\ e_{4t}^{clean\ energy\ return} \end{pmatrix} = \begin{bmatrix} a_{11} & 0 & 0 & 0 \\ a_{21} & a_{22} & 0 & 0 \\ a_{31} & a_{32} & a_{33} & 0 \\ a_{41} & a_{42} & a_{43} & a_{44} \end{bmatrix} \begin{pmatrix} \varepsilon_{1t}^{oil\ supply\ shock} \\ \varepsilon_{2t}^{aggregate\ demand\ shock} \\ \varepsilon_{3t}^{oil-specific\ demand\ shock} \\ \varepsilon_{4t}^{clean\ energy\ stock\ shocks} \end{pmatrix} \qquad (2)$$

Assumptions

- Crude oil prices are treated as endogenous,
- The model consists of two blocks: the global crude oil market and the clean energy market,
- There is a vertical short-run supply curve of crude oil and a downward-sloping short-run demand curve.

Studies examining the relationship between oil prices and macroeconomic aggregates have only examined the impact of oil price shocks, not the nature of shocks in general. Moreover, oil price fluctuations are considered exogenous and presumed to result from supply disruptions, mainly brought on by geopolitical risk factors (Hamilton, 1983; Hamilton, 2003; Kilian, 2008a; Kilian, 2008b, among others). Due to evidence that both supply disruptions and demand-related factors cause oil price shocks, this was recently shown to be incomplete (Kilian & Park, 2009: 1269; Kilian, 2009: 1058; Jadidzadeh & Serletis, 2017: 67; Demirer et al., 2020: 2). It's crucial to pinpoint the cause of the oil price fluctuations to more thoroughly analyse how oil prices affect financial markets. Due to their dissimilar natures, oil supply and demand shocks may have divergent economic consequences. For instance, price increases caused by supply shocks have a negative impact on economic activity, whereas price increases caused by oil demand shocks have a positive impact (Ready, 2018: 3). Assuming that crude oil prices are endogenous, we will explain changes in real oil prices in terms of three structural shocks: shocks to the global crude oil supply ("oil supply shock" denoted by ε_{1t}), shocks to the global demand ("aggregate demand shock" denoted by ε_{2t}), and shocks from changes in precautionary demand for oil ("oil-specific demand shock" denoted by ε_{3t}).

The model consists of two blocks, the global crude oil market (first block of Eq. (2)) and the clean energy stock market (second block of Eq. (2)). Fluctuations in the real price of oil in the global crude oil market block are explained by three structural shocks (ε_{1t}, ε_{2t}, ε_{3t}). There is only one structural innovation in the clean energy market block. This innovation, which represents clean energy stock shocks as ε_{4t}, is not caused by global crude oil demand or supply shocks but is not a true structural shock.

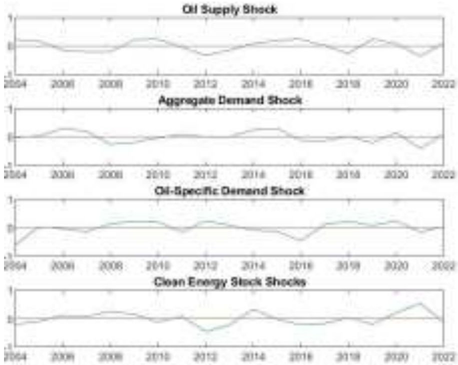
There is a vertical short-run supply curve of crude oil and a downward-sloping short-run demand curve. A sudden change in the real price of oil is the consequence of shifts in the demand curve, which are brought on by either aggregate demand shocks or oil-specific demand shocks, as well as unexpected shocks to the oil supply (Kilian, 2009: 1059).

5. Structural VAR Estimates

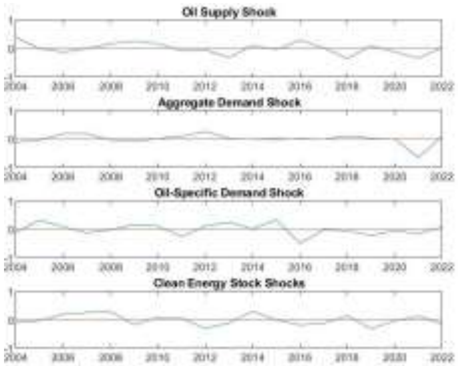
We consider dynamics with a delay of up to 24 months, following Kilian (2009: 1058) and Kilian & Park (2009: 1270). Using the least-squares method, we estimate the VAR in its reduced form. Using the obtained estimates, we construct the SVAR representation and calculate the VAR impulse responses by Cholesky decomposition for one-standard deviation structural innovations based on a recursive design with 2,000 replications.

The time path of the structural shocks that the model suggests is depicted in Figure 2. We note that while the oil supply disruption in the model with the ECO index occurred between 2006 and 2008, the oil supply disruption in the model with the NEX index occurred in 2006 and ended after 2007. The model with the ECO index experienced negative supply shock in 2012 is experienced by the model with the NEX index in 2013. Since 2014, shale gas and oil production in the US has increased, which has led to an increase in supply (Uçkun, 2016: 48). The model created using the ECO index makes it easier to see the positive effect of the rise in shale oil production on oil supply. This can be attributed to the ECO index's exclusive focus on US companies, in contrast to the NEX index. In the model with the NEX index, the aggregate demand shock does not produce any reaction between 2013 and 2020. This may be due to the NEX index's relative stability in comparison to the ECO index during this time, as well as the stability of the GECON index over the same time (see Figure 1). In the period between 2011 and 2014, the oil-specific demand shock and the oil supply shock are observed to move in opposite directions. In other words, the 2011 Arab Uprisings and the Euro Zone financial crisis reduced oil supply, exacerbating uncertainty and resulting in both models' unexpected rise in oil-specific demand in 2012. After the global pandemic, clean energy stock shocks soared, while all other shocks unexpectedly decreased. In addition, the model with the ECO index responds to clean energy stock shocks more quickly than the model with the NEX index.

Figure: 2
Historical Evolution of the Structural Shocks



Historical Evolution of the Structural Shocks with the ECO Index

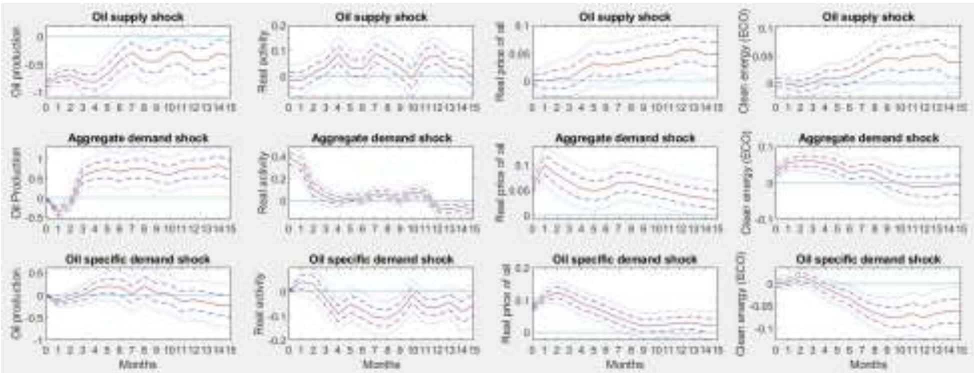


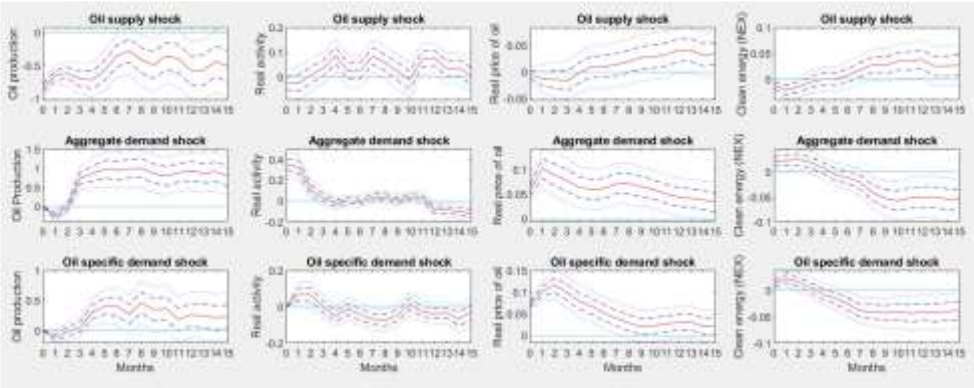
Historical Evolution of the Structural Shocks with the NEX Index
Source: Author’s calculations.

Figure 3 depicts the effects of the three structural shocks on global oil production, real economic activity, the real price of oil, and clean energy stock returns. We normalise the oil supply shock to represent a negative shock and the aggregate demand shock and the oil-specific demand shock to represent a positive shock, as done by Kilian (2009: 1060) and Kilian & Park (2009: 1272), such that all three shocks raise the real price of oil.

According to one-standard error bands, a sudden drop in global oil production has a positive and statistically significant effect on the returns of clean energy stocks starting from the seventh month in both models. In the first eight months of the model using the ECO index, aggregate demand expansions have a statistically significant positive immediate impact on the stock returns of clean energy companies. In addition, after the third month in both models, an unexpected rise in the precautionary demand for oil has a lasting statistically significant negative impact on the stock returns of clean energy companies. These outcomes are consistent with Zhao's (2020: 9) findings, which demonstrate that while oil-specific demand shock negatively affects clean energy companies' stock returns, oil supply shock positively affects those returns. The fact that the positive oil-specific demand shock has a negative impact on the stock returns of clean energy companies further supports the conclusion that oil and clean energy are not alternatives for one another. As crude oil production is long-term and capital-intensive, Wang et al. (2014: 27) underline the oil supply's low short-term price elasticity. Thus, the oil supply will not respond in the short term to changes in aggregate demand, price, or clean energy stock return. Because supply is currently reliant on the output of a small number of primary producers, a supply shock will only result in significant changes to overall oil production. Hence, a decline in oil supply and subsequent price increases would not, in the short term, spur investments in clean energy. Based on these findings, it is possible to conclude that clean energy and oil are not alternatives. This is corroborated by Desilver (2020), who argues that, despite the growing percentage of renewable energy in global energy consumption, fossil fuels continue to dominate in the US. This is due to the pressure that fossil fuel firms are ostensibly under to switch to renewable energy. Likewise, some companies have established a net zero emissions target and altered their names and branding (for instance, BP changed its name from "British Petroleum" to "Beyond Petroleum" to demonstrate that it is serious about the energy transition). Yet, the truth is that even though fossil fuel-based energy is currently more affordable to produce than renewable energy, the proportion of fossil fuels in global energy consumption has essentially remained constant over the past ten years. According to Hareesh Kumar (2021), oil and gas companies feel free to switch to clean energy, and most companies tend to put off their obligations to reduce emissions for as long as possible.

Figure: 3
Responses to the Three Structural Shocks





Source: Author's calculations.
Notes: One-standard error and two-standard error bands are represented by dashed and dotted lines, respectively.

The three structural shocks' impact on the returns for clean energy stocks is quantified by the forecast error variance decomposition given in Table 1. In the models with the ECO and NEX indices, the aggregate demand shock has the most significant explanatory power for the short-term variation in clean energy stock returns, with 10,25% and 7,62%, respectively. In the model with the ECO index, the oil-specific demand shock has the most explanatory power in the long term, whereas the aggregate demand shock has the most explanatory power in the model with the NEX index. Specifically, in the ECO index model, oil supply shocks account for around 10% of the long-term change in clean energy stock returns, whereas oil demand shocks in the crude oil market account for about 41%. On the other hand, oil demand shocks in the crude oil market contribute to roughly 49% of the long-term change in clean energy stock returns in the model using the NEX index, while oil supply shocks account for approximately 7%.

Table: 1
Per Cent Contribution of Three Structural Shocks in the Crude Oil Market to the Overall Variability of Clean Energy Stock Returns

Horizon	Oil supply shock	Aggregate demand shock	Oil-specific demand shock	Other shocks
1	0,05 (2,12)*	10,25 (7,63)	0,00 (2,30)	89,68 (87,93)
2	0,04 (4,46)	25,04 (8,05)	0,16 (4,87)	74,74 (82,60)
12	6,30 (6,21)	13,39 (15,84)	17,81 (12,45)	62,49 (65,49)
∞	9,77 (6,75)	10,15 (35,56)	30,54 (13,32)	49,52 (44,35)

Source: Author's calculations.
Notes: Based on variance decomposition of the structural VAR model (1).
** The results of the model with the NEX index are in parentheses.*

The cumulative contribution of three structural shocks that drive the crude oil market to the real price of crude oil is represented in Figure 4. Figure 4 implies that the oil supply shock and aggregate demand shock contribute similarly to the real price of oil and that these contributions are less than the contribution of the oil-specific demand shock. By the studies by Kilian & Park (2009: 1272-74), Kilian (2009: 1062), and Jadidzadeh & Serletis (2017: 70), we find that oil-specific demand shocks are the most important contributor to the abrupt spikes and drops in the real price of oil. According to Kilian (2009: 1062), the reason for this is that changes in precautionary demand are brought on by the anticipation of future oil supply shortages, and the market responds to these expectations very quickly.

Figure: 4
Historical Decomposition of the Real Price of Oil

Source: Author's calculations.

6. Clarifying the Substitution Effect

IEA (2021b: 3) strongly emphasises the significance of switching to clean energy to terminate the world's reliance on fossil fuels and achieve net zero emissions. This makes it crucial to investigate if clean energy has a substitutive effect on fossil fuels, particularly oil, which accounts for the biggest global energy consumption. Using monthly data for the vector of time series $z_t = (\Delta prod_t, gecon_t, rpoil_t, oilgas_t)$, we will estimate the SVAR model to highlight the substitution impact. $oilgas_t$ stands for the Dow Jones U.S. Oil and Gas Index (DJUSEN), which tracks the stock performance of US companies in the oil and gas industry. Datastream extracts the Oil and Gas Index, which is then calculated using log levels.

Before the global financial crisis of 2008, all indices were heading in much the same direction; however, after the crisis, the ECO and NEX indices had a sharp decrease, and the differences between the indices -particularly between the ECO and DJUSEN indices- began to widen (see Figure 5). The NEX index oscillates between the DJUSEN and ECO indices. As a result of the severe economic recession that the 2009 global financial crisis caused, the ECO index kept going down. When COP15[5] met in 2009, public concerns about climate change were the main topic of discussion. Most nations, particularly those in Europe and the US, have launched stimulus packages in this manner (IEA, 2020). Temporary stimulus packages, however, have harmed the renewable energy industry rather than helped it. Because the renewable energy sector is dependent on government support, it is particularly vulnerable to cutbacks during financial difficulties brought on by the current economic crisis. After the global financial crisis, subsidies were reduced in the EU member states. For

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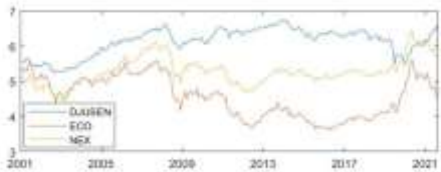
5 *The 15th Conference of the Parties to the United Nations Framework Convention on Climate Change.*

instance, the German government decreased its support for solar energy in 2010 and 2011 (Victor & Yanosek, 2011: 115).

In summary, due to inconsistent government support for the clean energy sector, global investments in renewable energy and the ECO index have fallen. Moreover, the Oil and Gas Index started to fall as the ECO index soared quickly with Covid-19. However, the rate of growth of the ECO index is significantly greater than the rate of decline of the Oil and Gas index. In addition, the NEX index has surpassed the DJUSEN index and is at its highest point ever. This is supported by a recent study by Wan et al. (2021: 1-2), which found that as governments implement green recovery plans in response to the pandemic, stock prices of clean energy companies increase. This attracts investors' attention to clean energy investments, leading to a rise in stock prices. Ghabri et al. (2021: 4962) also discovered the positive effect of the pandemic on the stock returns of renewable energy firms. The DJUSEN index has risen since 2021, despite the ECO and NEX indices declining. The importance of energy security, which encompasses the accessibility and affordability of energy resources, has been highlighted by the Russia-Ukraine conflict. As a result of the impossibility of a rapid transition to clean energy shortly, countries relying on Russian oil and gas have opted to obtain oil and natural gas from other countries. Countries planning to close their coal and nuclear power plants and speed their transition to clean energy have decided to defer their plans for now (Pfeifer, 2022).

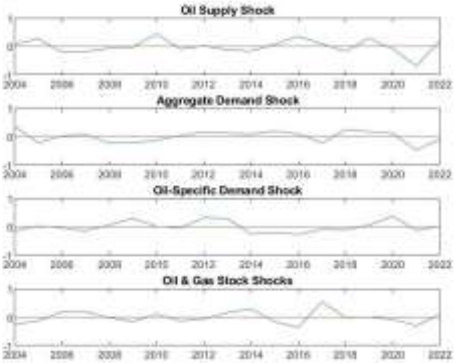
Figure: 5
Historical Evolution of the Oil and Gas (DJUSEN), the ECO and NEX Indices (in the log): 2001:01-2022:06



Source: Author's calculations.

Figure 6 shows that the increase in oil supply in the 2010s can be attributed to a major crude oil surplus that began in 2014-2015 and escalated in 2016. An oversupply resulted from the US entering the market as a new player (with shale oil production). As a result, oil prices started to drop after 2014. The oversupply brought on by American shale gas production and the decline in demand due to the downturn in China's economy, the world's largest energy consumer (Wong, 2015), contributed to the drop in oil prices. Also, we observe that oil-gas company stock returns have declined over this period. Besides, all shocks unexpectedly refuse following the global epidemic (however, clean energy stocks have increased since the onset of the worldwide pandemic, see Figure 2). According to Gollakota & Shu (2022), Covid-19 has a significant detrimental impact on the financial performance of dirty energy companies. Compared to other industries, the energy sector has a greater fixed-asset ratio and financial leverage, resulting in higher fixed and operational costs. As a result, throughout the Covid-19 period, the stock values of big energy companies like Royal Dutch Shell and BP declined significantly. Also, this process has given rise to the notion that switching to renewable energy is vital to decarbonise the world economy. Moreover, the decreasing cost of renewable energy sources has inspired many governments to establish increasingly ambitious goals for the switch to renewable energy.

Figure: 6
Historical Evolution of the Oil and Gas Stock Shocks



Source: Author’s calculations.

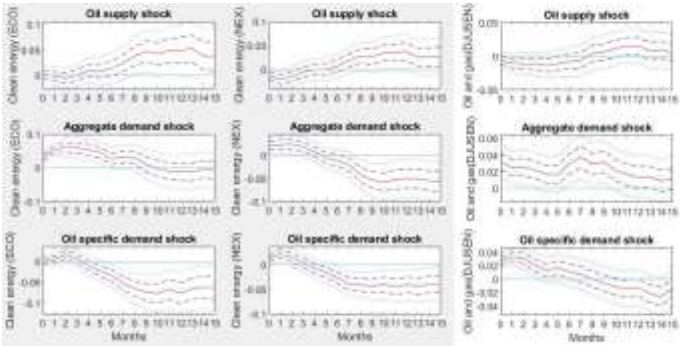
For a brief period (between the first and fourth months), an oil supply shock negatively and significantly impacts the returns for oil and gas stocks (see Figure 7). The findings of Kang et al. (2017: 349-50) indicating that a negative oil supply shock has a temporally statistically significant negative impact on the stock returns of oil and gas companies are consistent with this finding. The positive effect of a negative oil supply shock on the stock returns of clean energy companies claims that the rise in oil prices brought on by oil supply shocks causes investors to switch from oil to renewable energy sources, demonstrating the substitution effect between oil and clean energy. The outcome of the negative impact of the oil supply shock on oil and gas stock returns in this study does not, however, support the substitution effect that was produced by the positive impact of the oil supply shock on clean energy stock returns. Simply put, investors are anticipated to transfer from oil to clean energy due to rising oil prices brought on by a negative oil supply shock, resulting in higher stock returns for clean energy companies and lower stock returns for oil and gas companies.

We see that the aggregate demand shock has a long-lasting, considerable impact on the returns on oil and gas stocks. But over time, the aggregate demand shock's positive effect on oil and gas company stock returns diminishes (except for between the 5th and 7th months). Kang et al. (2017: 349) also find that aggregate demand shock positively impacts the stock returns of oil and gas companies and that this positive effect on stock returns increases over time. Similarly, Zhao (2020: 11), in his study utilising the Kilian index, finds that the positive impact of the aggregate demand shock on oil and gas stock returns in the first 20 months normally increases but falls in the final five months. Using the Kilian index, Maghyereh & Abdoh (2021: 8) also discovered that aggregate demand shock raises oil and gas company stock returns across the short-, medium-, and long-term.

In the first six months, the oil-specific demand shock has a statistically significant positive impact on the stock return of oil and gas companies, but this impact is waning over time. This finding is consistent with the findings of Kang et al. (2017: 349), and Zhao (2020: 11). Figure 7 shows that the stock returns of oil and gas and clean energy companies fall in response to a shock in the oil-specific demand. In other words, stock returns of both clean energy and oil and gas companies begin to fail when the price of oil increases due to an unexpected surge in precautionary oil demand. Concerning clean energy stock returns in particular, worries are growing about predicted oil supply shortfalls due to the ongoing turbulence in the oil market caused by Covid-19 and the quickly rising oil demand in emerging market nations like China and India. Hence, the current oil demand may increase if a future oil supply decline is anticipated. In other words, if the present oil demand grows, this can be a sign that oil producers aren't converting to renewable energy. On the other hand, Gupta (2016: 145-49) notes that the sensitivity of the stock returns of oil and gas companies to an increase in oil prices is substantially lower than a decline in oil prices, concentrating on 2136 active and dead/delisted stocks of oil and gas companies from 70 nations from 1983 to 2014. Additionally, he discovers that lower oil and gas stock returns result from the rise in global uncertainty. Maghyereh & Abdoh’s (2021: 9)'s observation that an oil-specific demand shock has a more significant impact on oil and gas company stock returns in a normal economic conditions confirms this result. Our period encompasses the 2008 global financial crisis, the 2011 Arab uprisings and Eurozone debt crisis, the global pandemic, and the Russia-Ukraine war, all contributing to global uncertainty. We can thus conclude that these uncertainties cause the stock returns of oil and gas companies to decline.

To sum up, a rise in oil prices caused by an oil-specific demand shock does not typically increase the stock return of oil and gas companies because their stock returns are more sensitive to the decline in oil prices and more affected by oil-specific demand shocks under normal economic conditions. Because the oil-specific demand shock lowers the stock returns of both clean energy and oil and gas companies, there is no substitution effect between oil and clean energy.

Figure: 7
Responses of the Oil and Gas Industry and Clean Energy Stock Return to the Structural Shocks



Source: Author's calculations.
Notes: One-standard error and two-standard error bands are represented by dashed and dotted lines, respectively.

In the long term, aggregate demand shock accounts for over 21% of the variation in oil and gas stock returns, oil-specific demand shock accounts for 13%, and oil supply shock almost entirely accounts for 9,5%. The aggregate demand shock best explains the variability of oil and gas stock returns.

Table: 2
Per Cent Contribution of Demand and Supply Shock to the Overall Variability of Oil and Gas Stock Returns

Horizon	Oil Supply Shock	Aggregate Demand Shock	Oil-Specific Demand Shock	Other Shocks
1	0,72	19,32	12,94	66,99
2	1,41	16,39	18,11	64,08
12	2,50	16,99	8,68	71,81
∞	9,48	20,73	13,08	56,69

Source: Author's contributions.
Notes: Based on variance decomposition of the structural VAR model (1).

7. Conclusions and Policy Implications

Using a structural VAR, this study attempts to answer how different oil price shocks affect the stock prices of clean energy and oil and gas companies. The analysis is motivated by the large swings in oil prices between 2001 and 2022 and how they affected the performance of the oil and gas and the clean energy stock returns. We consider the global economic conditions (GECON) index, which pinpoints shocks to aggregate demand.

The following are the key conclusions. First, both models using the ECO and NEX indices show that a negative oil supply shock positively impacts clean energy stock returns. Second, in the model using the ECO index, increases in aggregate demand have an immediate positive effect on the stock returns of clean energy companies. Third, in both models, the oil-specific demand shock negatively impacts the stock returns of clean energy. This indicates that increased oil prices due to an oil-specific demand shock do not motivate investors to switch to clean energy. Last, to further explain the substitution effect, it is also noted that when the impact of oil price shocks on both clean energy and oil and gas stock returns are compared, the rise in oil prices caused by the oil-specific demand shock does not generally increase the stock returns of oil and gas companies. This is because the stock returns of oil and gas companies are more sensitive to the decrease in oil prices and are more affected by oil-specific demand shocks under normal economic conditions. Consequently, the prior findings imply that oil and clean energy are not substitutes for one another.

The absence of the oil-to-clean energy substitution effect can be attributed to several factors. First, the primary energy sources in the world's energy consumption are still fossil fuels, even though the share of renewable energy is rising. Second, oil and gas companies are not pressured to convert to renewable energy. Finally, the recent conflict between Russia and Ukraine has made it clear that delaying a nation's decision to phase out fossil fuels has a negative impact on clean energy stock returns.

Rising oil prices are likely to spur an increase in investments in clean energy and provide a substitution effect between oil and clean energy. However, there need to be more than high oil prices to accelerate the transition to clean energy sources. Government action should facilitate this transition, as investments in clean energy are more likely to expand when stable government subsidies are adopted in clean energy and the costs of renewable energy technology decrease. Yet, this situation can alter when there is a great deal of ambiguity, like with Covid-19. We saw a surge in the stock returns of clean energy companies and a fall in the stock returns of oil and gas companies, for instance, despite oil prices falling with Covid-19. This demonstrates that investor sentiment changes when significant uncertainty occurs during financial and economic crises. The renewable energy industry can successfully compete with oil even while oil prices fluctuate at recent lows. Consequently, it is left to future studies to study the substitution effect between oil and clean energy by integrating government intervention and investor sentiment in the model.

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