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RESEARCH ARTICLE

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The resilience of green firms in the twirl of COVID-19: Evidence from S&P500 Carbon Efficiency Index with a Fourier approach

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Abstract

This paper investigates the resilience of environmentally friendly companies in an overwhelming economic and social environment that has been generated after the outbreak of the novel coronavirus disease (COVID-19) pandemic. To this respect, we have investigated the cointegration between the Standard & Poor's (S&P) 500 Carbon Efficiency Index (CEI) with COVID-19 cases, supplemented with covariates such as government response stringency to the pandemic, economic policy uncertainty, oil prices and global markets fluctuations. We have used daily data from 2nd January to 5th October 2020 and have employed a robust estimator within a Fourier approach to accommodate both sharp and smooth breaks. Our results suggest that green companies have been positively affected by the outbreak of COVID-19. Our paper provides practical implications for companies that wish to furnish themselves with resilience during rough times and stakeholders who wish to invest in safe, long-lasting returns.

KEYWORDS

Carbon Efficiency Index, COVID-19, government response, green investment, stakeholder engagement, sustainable development

1 | INTRODUCTION

The Paris Agreement in 2015, ratified by 196 countries, can radically change economies, societies and the environment on a local, national, regional and global scale. First, United Nations (UN) countries agreed on limiting the global temperature rise, well below 2°C after what was in the Industrial Revolution (Monasterolo & de Angelis, 2020). In line with this goal, reducing greenhouse gas emissions has become a priority target (Benz et al., 2021; Işik et al., 2017, 2021; Ongan et al., 2021). The second issue that countries agree on is the need to provide climate finance, green investment, green technology and capacity-building support to implement the transformation to provide low-carbon and climate-resistant development (Peake & Ekins, 2017). It is imperative to transform its economic and financial policies from traditional methods to environmentally friendly and sustainable ones (Benz et al., 2021; Isik et al., 2019, 2021). In the period following the Paris Agreement, many governments and companies began increasing their commitment to set an aim for net-zero carbon dioxide (CO_2) emissions in the following decades as a part of their global efforts to meet long-term sustainability goals (International Energy Agency [IEA], 2020). The use of essential and effective tools to promote a low-carbon economy and reduce greenhouse gas emissions, such as green bonds, green loans, sustainable bonds and carbon stocks, has become widespread

Abbreviations: UN, United Nations; CO_2, Carbon Dioxide; COVID-19, Coronavirus; S&P500 CEI, Standard & Poor's 500 Carbon Efficient Index; ESG, Environment, Social and Economic and Governance; CBOE VIX, Chicago Board Options Exchange Volatility Index; DAX, Germany Stock Market Index; NIKKEI, Tokyo Stock Market Index; BIST, Istanbul Stock Market Index; EPU, Economic Policy Uncertainty; OxCGRT, COVID-19 Government Response Tracker; OLS, Ordinary Least Squares; FMOLS, Fully Modified Ordinary Least Squares; CCR, Canonical Cointegration Regression.

(Banga, 2019; Benabdellah et al., 2021; Fatica & Panzica, 2021; Palea & Drogo, 2020; Tolliver et al., 2020).

However, in late 2019, the coronavirus disease (COVID-19) emerged and changed the political and economic agenda significantly when sustainable financial instruments were continually evolving and reaching high penetration in businesses. As it turned out to be, the global public health emergency has led to a health crisis and a severe economic crisis (Q. Wang & Wang, 2020). Governments worldwide began implementing unprecedented policy actions to combat the virus, provide adequate health care and prevent an economic collapse (Steffen et al., 2020). Many countries began to reduce fossil fuel consumption and the subsequent carbon taxes and to reclaim environmental regulations. The focus was on bailing out big auto, oil and tourism companies, while the airline industry has regarded environmental issues as a non-priority issue within the pandemic turmoil. Hence, the pandemic and the economic impacts it triggers affect long-term efforts to limit greenhouse gas emissions under the Paris Climate Agreement (Reilly et al., 2021).

Country-level policymakers focused on discussing policies to boost economic recovery, namely, to create jobs and reduce poverty. Before the pandemic outbreak, environmental issues were considered one of the top five business risks and priorities. The year 2020 was expected to be a turning point for climate action (Mukanjari & Sterner, 2020). In such a turbulent context, the urgency imposed by the pandemic does not leave room to prioritise sustainable environmental and energy policies. Thus, the answer to the question of how green businesses are affected by the pandemic is intriguing. Assuming this as starting point, we will evaluate the impact of the COVID-19 outbreak on stock markets.

Our paper contributes to the scant literature on how sustainable businesses were affected by the pandemic. It explains how the Standard & Poor's (S&P) 500 Carbon Efficiency Index (CEI) from the environmental (E), social (S), and economic and governance (G) (ESG) family has responded to the increase in COVID-19 cases. Understanding the response of low-carbon company shares to health-related economic and financial shocks/crises can be a future guide, especially in designing corporate sustainable development policies. It can also contribute to developing innovative strategies resulting from new understandings of the relationship between business, society and nature (Edwards, 2021). Our study fulfils its main goal while implementing four other novelties.

First, it is the first paper to contribute to the literature of the investigation of the impacts of the COVID-19 pandemic on the S&P500 CEI in an environment of uncertainty and fluctuation in global markets. Second, it provides new insights into low-carbon companies' economic endurance capacity by estimating the impact of economic uncertainty on the S&P500 CEI. It should be emphasised that the uncertainty of the economic environment plays a vital role in the strategy formulation and management decisions of firms (Mirza & Ahsan, 2020). Third, it estimates the impact of oil prices and governmental response on the S&P500 CEI. Fourth, it focuses on the USA, which is the leading world market. Also, the US stock market is recognised as a global market. Movements in the US stock market concern all developed and developing markets and thus can cause a spillover effect (Shehzad, Xiaoxing, et al., 2021). The most striking index of the US stock market is the S&P500. This index is weighted by the values of the 500 largest publicly traded companies in the USA. It is considered to be the best indicator of the US stock market. Global markets closely monitor the S&P500 index performance. Its total market value is currently the US$31.6 trillion. Finally, it considers both sharp and gradual breaks in this empirical analysis through a Fourier approximation, thus giving its more accurate and realistic findings.

The rest of the paper is organised as follows: Section 2 presents the literature review with a conceptual framework. Section 3 explains the materials and the methodology. Section 4 reports and discusses the empirical findings. Section 5 concludes the paper.

2 | A LITERATURE REVIEW AND THE VARIABLE SELECTION

In this section, the paper presents the extant literature about the impact of the COVID-19 pandemic on stock markets and the variable selection for the empirical model estimated.

2.1 | Literature review

Prior to the COVID-19 pandemic, financial markets were exposed to huge shocks in the last two decades: terrorist attacks in the USA on 11 September 2001 and the global financial crisis in 2007–2008. Within this scope, one can observe from the existing finance/financial economics literature that many papers investigated the impacts of these developments on stock markets. For instance, while some papers examined the impact of the 11 September attacks on stock markets (see, e.g., Aksoy, 2014; Charles & Darné, 2006; Glaser & Weber, 2005; Hon et al., 2004; Nikkinen & Vähämaa, 2010, among others), some others investigated the influence of the global financial crisis on stock markets (see, e.g., Dimitriou et al., 2013; Jin & An, 2016; Luchtenberg & Vu, 2015; Mun & Brooks, 2012; Nobi et al., 2014; G. J. Wang et al., 2017; Yarovaya & Lau, 2016; J. B. Zhang, Gao, & Cai, 2020, among others).

When it comes to analysing the influence of the COVID-19 pandemic on stock markets, one can notice that the fastest response to the increasing risks and uncertainties caused by the pandemic came from the global financial markets. Sharp decreases were observed in the US stock markets in the second week of March 2020. When the decrease rate in the S&P500 index rose above 7% daily, circuit breakers entered into practice and stopped the transactions for 15 min (Neurath, 2020). The S&P500 stock market index responded to the news of the disease by going down by 33.7% between 19 February and 23 March 2020 (Cox et al., 2020). During the same period, Dow Jones, FTSE 100, DAX, NIKKEI 225, Shanghai and BIST 100 lost value by 34%, 34%, 35%, 27%, 14% and 29%, respectively (Bloomberg, 2008). Moreover, the rise in the Chicago Board Options Exchange Volatility Index (CBOE VIX), which is considered as one of the leading indicators of the business cycles and which reflects the volatility in global markets, was very close to the value it had assumed in the 2008 global financial crisis (Fasan et al., 2021; Just & Krzysztof, 2020; Salisu & Akanni, 2020). The CBOE VIX value, which reached 80 points during the 2008 global financial crisis, reached the same level at the end of March 2020 (see Figure 1). This value reveals the economic and financial crisis in the markets. After the first impact of the health shock on global financial markets, many academics investigated the relationship between COVID-19 and stock markets.

The first group of these studies confirmed that COVID-19 had harmed global stock markets. Topcu and Gulal (2020) examine the impact of the COVID-19 pandemic on the stock markets of developed and developing countries. Their findings showed that the pandemic had affected all country stock markets, but the most severe impact has occurred on the Asian stock markets. The slightest effects were observed on the European stock markets. In addition to that, the research explored that the official response time and the stimulus package provided by governments were important in balancing the effects of the COVID-19. Ashraf (2020a, 2020b) has analysed the impact of the COVID-19 and government responses on the international stock markets and economic activities. This study showed that the number of cases, social distancing and other lockdown practices hurt stock markets and economic activities. Moreover, other papers in the extant literature confirmed similar results (Liu et al., 2020; Shehzad, Bilgili, et al., 2021; Zaremba et al., 2021; D. Zhang, Hu, & Ji, 2020).

The second group pointed out that the decrease in stock returns caused by the COVID-19 outbreak had a spillover effect across global markets (Aslam et al., 2021; Corbet et al., 2021; Hanif et al., 2021; Shehzad, Xiaoxing, et al., 2021; Yarovaya et al., 2021). These studies showed that the panic and fears of investors have dramatically influenced the global markets.

The third group of studies examined the impact of the COVID-19 pandemic on stock returns at the sectoral level. He et al. (2020) revealed that the pandemic in China negatively influenced stock prices in transportation, mining, electricity, heating and environmental industries. On the other hand, some researchers concluded that stocks in the manufacturing, information technology, education and healthcare industries were more resistant to the pandemic. Alam et al. (2020) examined the sectoral effects of COVID-19 on the Australian stock exchange. According to that study, while telecommunication, technology, food, medicine and health services indices generated positive returns against the pandemic, energy, real estate and transportation indices generated negative returns. Besides, some researchers implied that the COVID-19 outbreak had a drastic lowering effect on the tourism and travel industry stock prices (Liew, 2020; X. Lin & Falk, 2021; Nhamo et al., 2020; Sharma & Nicolau, 2020; Uğur & Akbıyık, 2020).

2.2 | Variable selection

It is seen that the information on sustainable business models and stocks is more limited, and there is a newly developing literature in this area. One of the pioneering and remarkable financial indicators that take the sustainability criteria into account is the ESG family. S&P Dow Jones Indices (DJI) first began the Dow Jones Sustainability World Index launch in 1999 in partnership with S&P Global and has been a pioneer in ESG indexing for nearly 20 years. Additionally, S&P DJI has begun to leverage more sustainability data to offer a more comprehensive ESG index range from 2019 (S&P Global, 2020). Thus, the current literature began to research the performance of the ESG family. There has been tremendous interest in the relationship between environmental performance and financial performance in particular over the past decade (Garcia-Blandon et al., 2020; Rahman et al., 2020). The pioneering research in this focus shows that stocks with high ESG scores generate positive abnormal returns (Derwall et al., 2005; Statman & Glushkov, 2009). Some studies have criticised that ESP performance as it is not fully reflected in stock prices (Edmans, 2011; Mănescu, 2011). In another respect, very little research has examined the degree to which sustainable financial instruments have reacted to the COVID-19 pandemic. Broadstock et al. (2021) have recently investigated the ESG performance against financial shocks during the COVID-19 pandemic in China. Their findings showed that higher ESG portfolios had outperformed financial crises and reduced financial risks. Takahashi and Yamada (2021) analysed stock returns during the COVID-19 outbreak in Japan, considering the ESG index companies. Results from this study revealed

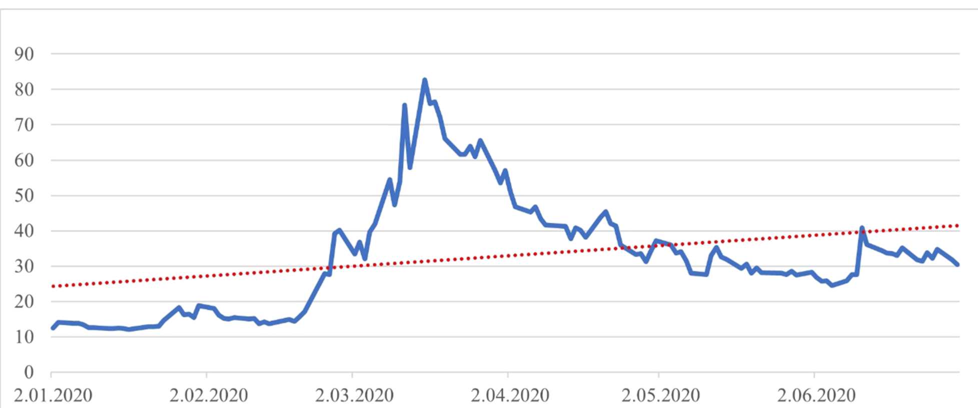

FIGURE 1 Chicago Board Options Exchange Volatility Index (CBOE VIX) (2020:M01–2020:M06). Source: Investing Database (Investing.com, 2020) [Colour figure can be viewed at wileyonlinelibrary.com]

no evidence that company stocks with higher ESG scores had higher returns. Folger-Laronde et al. (2020) explored how exchange-traded funds with a high ESG rating responded to financial shocks caused by the COVID-19 pandemic. The results showed that stock exchange-traded funds with higher performance on environmental sustainability did not protect investments against financial losses during the severe market downturn.

Furthermore, by including the CBOE VIX indicator in the empirical model, we also try to explain the impact of fears and fluctuations in global markets on the S&P500 CEI in the USA during the COVID-19 pandemic in the present paper. During the COVID-19 pandemic, there is a worldwide economic policy uncertainty (EPU) because of the inability of policymakers to reach consensus and stability in economic policies. Uncertainty in economic policy decisions negatively affects many decision dynamics, such as consumption, investment, saving and lending, negatively affecting the global economy, not least the stock markets (Dakhlaoui & Aloui, 2016; Wu et al., 2016). Uncertainty can intensify the lack of investment and economic contraction through its detrimental effect on the supply–demand channels, thereby increasing financing and production costs. EPU can raise inflation, interest rate and the expected risk premiums (Arouri et al., 2016). It also affects all assets, such as oil, agricultural products, gasoline and housing, destabilising commodities and other markets. EPU could also have dramatic effects on the cryptocurrency markets and their potential growth. Therefore, it should be underlined that EPU is a critical risk factor (Al-Thaqeb et al., 2020).

The COVID-19 pandemic has generated worldwide unprecedented uncertainty. During the pandemic, the EPU index reached

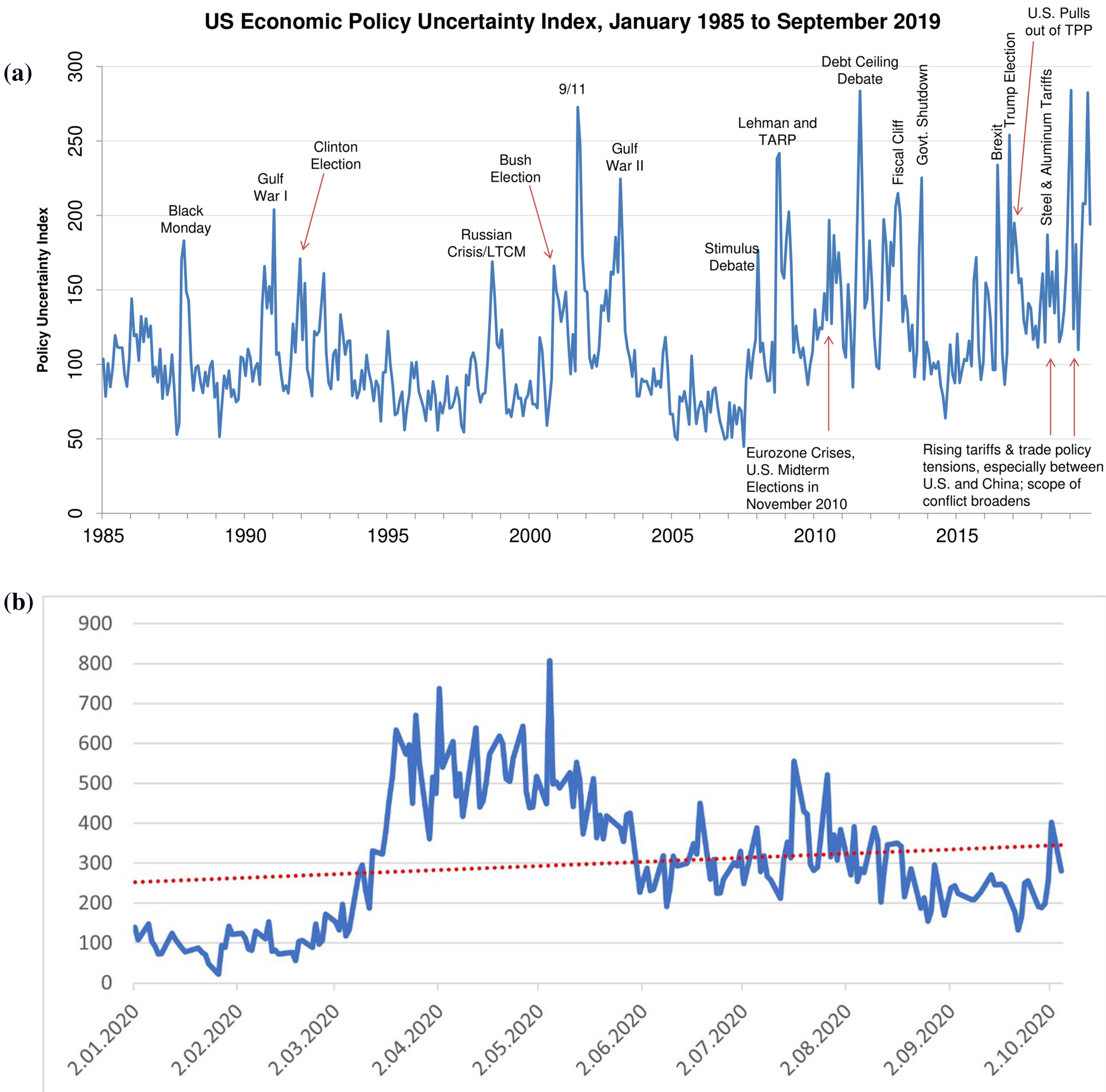

FIGURE 2 (a) Economic policy uncertainty index for the USA before the COVID-19 pandemic (updated version). Source: Baker et al. (2016). (b) Economic policy uncertainty index for the USA after the COVID-19 pandemic (updated version). Source: https://www.policyuncertainty.com/ [Colour figure can be viewed at wileyonlinelibrary.com]

all-time highs, including the times of the Gulf War, 11th September 2008, the global financial crisis (see Figure 2a,b). More importantly, no previous infectious disease outbreak, including the Spanish Flu, had hit the stock market as strongly as the COVID-19 did (Baker et al., 2020). The COVID-19 pandemic and the uncertainty it triggered are systematic sources of risk. Therefore, more research is needed on the economic impacts of pandemics and uncertainty (Sharif et al., 2020). Besides, our knowledge about the economic resilience capacity of sustainable financial instruments is still limited. Economic resilience capacity is defined as the ability of an asset to cope with any uncertainty or adversity (Uddin et al., 2021).

An extraordinary situation during the pandemic period is the sharp fall in oil prices (see Figure 3). Two months after the COVID-19 outbreak, oil prices decreased by about 30%, which has been the most significant drop since the Gulf War (Salisu et al., 2020). An enormous literature suggests that fluctuations in oil prices significantly affect stock returns (see, e.g., Hedi Arouri & Khuong Nguyen, 2010; Hon et al., 2004). Theoretically, the value of a stock is equal to the discounted sum of the expected future cash flows. Discounted cash flows are affected by macroeconomic magnitudes, such as inflation, interest rates, production costs, income, economic growth, investment, consumer confidence, and so forth. Oil price shocks, on the other hand, can directly affect macroeconomic conditions. Therefore, changes in oil prices affect stock returns positively or negatively depending on the sector (Hedi Arouri & Khuong Nguyen, 2010). Companies have unique abilities to achieve and advance sustainable development goals (van Zanten & van Tulder, 2021). The way low-carbon and ESG-based company stocks respond to fluctuations in oil prices is critical for sustainable development. Several papers examine the impact of oil price fluctuations on clean energy and technology companies (Bondia et al., 2016; Ferrer et al., 2018; Nasreen et al., 2020). However, there is still a research gap in the literature regarding the response of shares in the ESG family to changes in oil prices. This paper aims to fill the gap in the literature by analysing the impact of oil prices on the S&P500 CEI.

Government responses are vital to combat COVID-19 and to overcome the pandemic-induced economic depression. The government's responses to the COVID-19 pandemic could significantly affect the lives, health and the way of living. Governments worldwide are currently implementing a significant number and a variety of policies in response to the COVID-19 outbreak, covering specific periods (such as 1, 3 and 5 months) depending on the gravity of the problems the pandemic has caused and the particular framework. Policymakers have limited knowledge of whether, how and to what extent these rapidly changing policies are effective in mitigating health, political and economic impacts of the pandemic (Cheng et al., 2020). Moreover, our study explains the impact of government responses on the S&P500 CEI during the pandemic. We consider the indicators developed by the COVID-19 Government Response Tracker (OxCGRT) to measure governments' responses to the COVID-19 outbreak (Hale et al., 2020). The government's response to the pandemic is evaluated in three ways: stringency of measures, containment health and economics. The stringency index is calculated by considering lockout policies such as social distance, travel barriers, school closure, workplace closure, cancellation of public activities, assembly restrictions and the closure of public transport. The containment health index is calculated through public awareness, awareness campaigns, virus testing policy, quarantine and communication monitoring processes. The economic response index includes income support, debt/contract reduction, financial and international support (Ashraf, 2020a, 2020b). Finally, the average value of these three indicators is considered the government's response to the COVID-19 pandemic. This paper aims to provide novel information by explaining the S&P500 CEI's reaction to government responses in the outbreak.

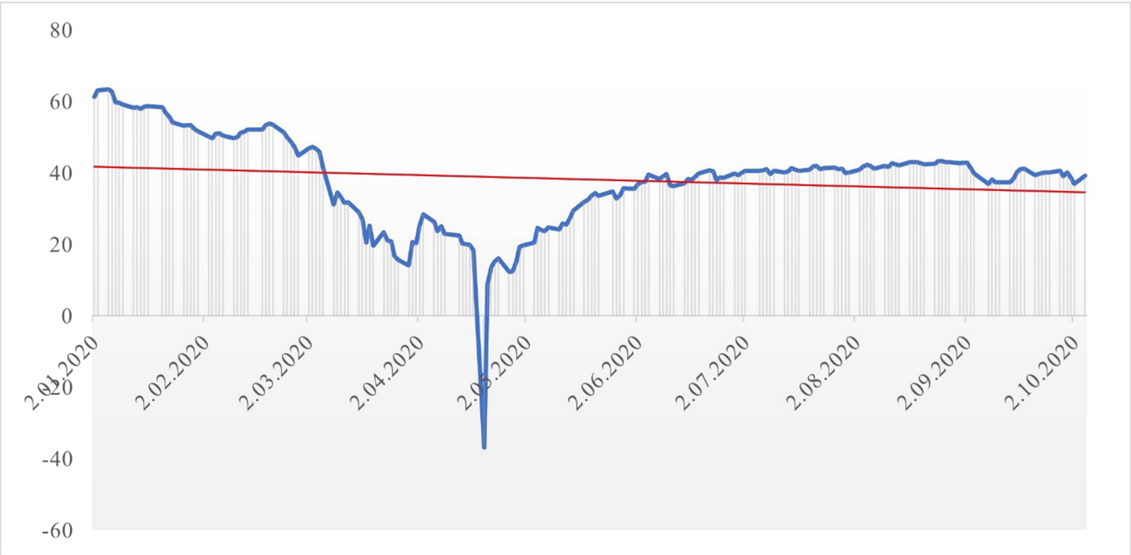

FIGURE 3 US daily oil prices (dollars per barrel/2020:M01–2020:M10). Source: U.S. Energy Information Administration (EIA) (2021) [Colour figure can be viewed at wileyonlinelibrary.com]

Last but not least, all the variables mentioned above considerably changed depending on the increases and decreases in confirmed COVID-19 cases and deaths due to COVID-19. Put differently, they were exposed to structural breaks during the observed period. Within this scope, Banerjee et al. (2017) note that empirical research may end up with inefficient findings if structural breaks pertinent in economic variables are ignored. Additionally, Becker et al. (2006) stress that the number and the form, namely, sharp or smooth, of these breaks may be unknown. Hence, we consider both sharp and smooth breaks in the empirical analysis in the paper. In doing so, we try to reveal efficient and unbiased results about the response of S&P500 CEI to the COVID-19 pandemic, EPU, oil prices, market volatility and government response.

3 | MATERIALS AND METHODOLOGY

The S&P500 ESG index, which is based on environmental, social and governance data and points to a new change in sustainable investment, is an important initiative as a sustainable business model. The S&P500 ESG index is a market value-weighted indicator developed to measure the performance of securities that meet sustainability criteria while maintaining similar industry group weights with the S&P500 (Clementino & Perkins, 2020; Rajesh, 2020; Rajesh & Rajendran, 2020). Within the ESG index family, the S&P500 CEI is designed to (i) combat climate change, (ii) address the transition to a low-carbon economy and (iii) measure the emission performance per unit income of companies in the S&P500. CEI rewards companies with a lower carbon footprint and is critical to encourage the transition to alternative long-term low-carbon business models.

In the current study, we launch a model to explain the impact of COVID-19 cases, government response, EPU, oil prices and VIX on the S&P500 CEI in the USA. As Erdem (2020) denotes, the number of cases serves as an early warning signal. It roughly gives information about the future death rates, implying the number of deaths may not present new solid information about the pandemic. Therefore, following Anh and Gan (2020), Ashraf (2020a, 2020b), Erdem (2020) and Sharif et al. (2020), the paper gauges the severity of the COVID-19 pandemic using cases. In Equation 1, β_0, β_1, ..., β_5 indicate the estimation parameters. The period and the error term are denoted by t and ε, respectively. lnCEI, lnCOVID, lnGRSI, lnEPU, lnOILP and lnVIX represent S&P500 CEI, COVID-19 cases, government response, EPU, oil prices and fluctuation/fear in global markets, respectively.

$$\text{lnCEI}_t = \beta_0 + \beta_1 \text{lnCOVID}_t + \beta_2 \text{lnGRSI}_t + \beta_3 \text{lnEPU}_t + \beta_4 \text{lnOILP}_t + \beta_5 \text{lnVIX}_t + \varepsilon_t \quad (1)$$

Data are daily, and the period range covers from 2nd January 2020 to 5th October 2020. We use the natural logarithmic form of the series denoted by ln. Table 1 shows summary information about the variables.

Table 2 depicts the descriptive statistics and the correlation matrix. The descriptive statistical values of all variables are close, in size, to each other. The variable with the highest mean and median value is lnCOVID. Standard deviation values of the variables are in the range of 0.09–0.3. All variables except for the lnVIX do not follow a normal distribution. According to the correlation matrix, lnCEI is positively correlated with lnCOVID and lnOILP. Besides, it is negatively correlated with lnGRSI, lnEPU and lnVIX. There is no high correlation between the independent variables. As it is widely known, descriptive statistics and correlation findings provide some initial information about the relationship among the variables. Next, we follow advanced statistical and econometric methods to reach more robust and consistent findings in the paper.

3.1 | The unit root testing

The unit root tests developed by Zivot and Andrews (1992), Lumsdaine and Papell (1997), Lee and Strazicich (2003) and Narayan and Popp (2010) are widely employed in econometric analyses. These tests consider a definite number of structural breaks and postulate that breaks in a series occur instantaneously, thus implying the existence of sharp breaks. Hence, these tests are likely to produce inaccurate and inefficient findings of the stationarity levels of series when (i) the number of breaks is unknown and (ii) there might exist

TABLE 1 Definitions of variables and data sources

Variable	Abbreviation	Definition	Source
S&P500 Carbon Efficiency Index	lnCEI	Performance indicator of low-carbon company stocks in the S&P500	Investing Database
COVID-19 cases	lnCOVID	The cumulative increase in the number of confirmed COVID-19 cases	Johns Hopkins Coronavirus Resource Center
Government response stringency index	lnGRSI	The overall government response index	Hale et al. (2020)
Economic policy uncertainty	lnEPU	Indicator developed to measure policy-related economic uncertainty	Baker et al. (2016)
Oil prices	lnOILP	Daily price per barrel of WTI crude oil (dollars per barrel)	EIA
Market volatility	lnVIX	Chicago Board Options Exchange Volatility Index	Investing Database

TABLE 2 Descriptive statistics and the correlation matrix

Descriptive statistics	lnCEI	lnCOVID	lnGRSI	lnEPU	lnOILP	lnVIX
Mean	5.998	7.826	3.454	5.522	3.591	3.323
Median	6.035	10.125	4.204	5.629	3.690	3.320
Maximum	6.144	11.250	4.286	6.694	4.147	4.415
Minimum	5.666	0.000	0.000	3.102	2.187	2.493
Std. dev.	0.096	0.297	0.217	0.302	0.195	0.223
Jarque–Bera	48.898*	43.962*	86.504*	16.417*	58.791*	0.307
Observation	191	191	191	191	191	191
Correlation matrix						
lnCEI	1					
lnCOVID	.182*	1				
lnGRSI	−.577*	.383*	1			
lnEPU	−.634*	.405*	.815*	1		
lnOILP	.730*	−.223*	−.819*	−.823*	1	
lnVIX	−.806*	.095	.615*	.653*	−.828*	1

*Denotes 1% statistical significance.

smooth breaks. Enders and Lee (2012) propose a unit root test that can provide robust results regardless of the number and structural breaks. Thus, we assume a model as in Equation 2.

$$y_t = \alpha(t) + \rho y_{t-1} + \gamma t + \varepsilon_t \tag{2}$$

In Equation 2, while ε is the stationary error term, $\alpha(t)$ denotes a deterministic function for t. To capture both sharp and smooth breaks, Enders and Lee (2012) use the following regression that is extended with a Fourier approach component:

$$\alpha(t) = \alpha_0 + \sum_{k=1}^{n} \alpha_k \sin(2\pi kt/T) + \sum_{k=1}^{n} \beta_k \cos(2\pi kt/T), \quad n \leq T/2 \tag{3}$$

where n is the number of frequencies, k is the frequency and T indicates the number of observations. In their original work, Enders and Lee (2012) consider the existence of a single frequency and use the model defined as

$$\Delta y_t = \rho y_{t-1} + c_1 + c_2 t + c_3 \sin(2\pi kt/T) + c_4 \cos(2\pi kt/T) + e_t \tag{4}$$

The null hypothesis of a unit root is defined as $\rho = 0$. When the test statistic is higher than the critical values that depend on the sample size and the frequency, the null hypothesis is rejected, meaning the series is stationary.

3.2 | Cointegration analysis

Although the cointegration tests developed by Gregory and Hansen (1996), Hatemi-J (2008) and Maki (2012) are widely employed in the economics literature, these tests can accommodate only a small number of sharp breaks. Hence, in the presence of an unknown number of gradual breaks, these tests are likely to produce spurious results. Following the Fourier methodology, Tsong et al. (2016) develop a cointegration test that allows for an unknown number of breaks. Their test considers both sharp and smooth breaks as well. Besides, a great advantage of this test is that it suggests a preliminary test to examine whether the test should be utilised to investigate cointegration. Tsong et al. (2016) first consider the model described as

$$y_t = d_t + x_t'\beta + \eta_t, d_t = \delta_0 + f_t, \eta_t = \gamma_t + \upsilon_{1t}, \gamma_t = \gamma_{t-1} + u_t, x_t = x_{t-1} + \upsilon_{2t} \tag{5}$$

where the error term and the Fourier function are, respectively, represented by u_t and f_t. The Fourier component is described as per Equation 6:

$$f_t = \alpha_k \sin\left(\frac{2k\pi t}{T}\right) + \beta_k \cos\left(\frac{2k\pi t}{T}\right) \tag{6}$$

In Equation 6, k denotes the Fourier frequency, t denotes the time trend and T denotes the number of observations. The null hypothesis of cointegration is defined as per Equation 7:

$$H_0 : \sigma_u^2 = 0 \text{ versus } H_1 : \sigma_u^2 > 0 \tag{7}$$

To test for the null hypothesis, the empirical model is established as per Equation 8:

$$y_t = \sum_{i=0}^{m} \delta_i t^i + \alpha_k \sin\left(\frac{2k\pi t}{T}\right) + \beta_k \cos\left(\frac{2k\pi t}{T}\right) + x_t'\beta + \upsilon_{1t} \tag{8}$$

Tsong et al. (2016) have computed their proposed test statistic as per Equation 9:

$$\mathrm{CI}_f^m = T^{-2}\widehat{\omega}_1^{-2}\sum_{t=1}^{T} S_t^2 \tag{9}$$

In Equation 9, $S_t = \sum_{t=1}^{T}\widehat{\upsilon}_{1t}$ represents the partial sum of the residuals of Equation 8 obtained through the ordinary least squares (OLS) method. Also, $\widehat{\omega}_1^2$ indicates the estimator of the long-run variance of υ_1.

As aforementioned, Tsong et al. (2016) also test whether the model should include a Fourier approach component. The null hypothesis implying there is no need to add the Fourier component is set up as H_0: $\alpha_k = \beta_k = 0$.[1] Equation 8 can be estimated via either the fully modified OLS (FMOLS) estimator developed by Phillips and Hansen (1990) or the canonical cointegration regression (CCR) estimator produced by Park (1992).

4 | RESULTS AND DISCUSSION

This section presents the Enders and Lee (2012) unit root test results and the Tsong et al. (2016) cointegration test. The findings obtained from the E&L unit root test are reported in Table 3. Both the model without trend and the model with trend indicate the same results in terms of integrating the variables in the empirical model. Accordingly, the null hypothesis of a unit root cannot be rejected at level, whereas it can be rejected at first differences at 1% level of significance for all variables. Hence, the unit root test's results reveal that all variables are integrated of order one and that the cointegration relationship in the empirical model can be examined through the Tsong et al. (2016) cointegration test.

The Tsong et al. (2016) cointegration test results along with the coefficients of the independent variables in the model are depicted in Table 4. Accordingly, panel A of the table presents the results of the cointegration estimation through the FMOLS estimator. Panel A1 shows that the null hypothesis of the absence of the Fourier component in the model can be rejected at 1% level, implying the cointegration relationship can and should be tested via the Tsong et al. (2016) cointegration test. Moreover, the null hypothesis of cointegration cannot be rejected, and this supports the existence of cointegration in the model. Finally, parameter estimations produced by the FMOLS estimator are provided in panel A2. Accordingly, lnCOV, lnGRSI, lnEPU, lnOILP and lnVIX, respectively, are estimated as of .009, .021, −.082, .052 and −.144 and are statistically significant. Therefore, the FMOLS estimator yields that lnCEI is positively affected by lnCOV, lnGRSI and lnOILP and is negatively affected by lnEPU and lnVIX.

To check the robustness of the findings indicated by the FMOLS estimator, we have further perused the CCR estimator. Therefore, panel B in Table 4 provides the results of the cointegration estimation via the CCR estimator. Panel B1 shows the null hypothesis for the absence of the Fourier component in the empirical model is rejected at 1% level, indicating the cointegration relationship should be analysed in the way suggested by the Tsong et al. (2016) cointegration test. Furthermore, the null hypothesis of cointegration is not rejected, implying the presence of cointegration in the empirical model. Last, the coefficient estimations suggested by the CCR estimator are shown in panel B2. Accordingly, the coefficients of lnCOV, lnGRSI, lnEPU, lnOILP and lnVIX are .009, .121, −.088, .051 and −.138, respectively, and are statistically significant. Therefore, the CCR estimator reveals that lnCEI is positively related to lnCOV, lnGRSI and lnOILP and is negatively affected by lnEPU and lnVIX. Overall, the FMOLS findings and the CCR estimators yield the same results in terms of the signs, statistical significance and even almost the magnitude of the coefficients of the independent variables.

TABLE 3 E&L unit root test

	Model without trend		Model with trend	
Variable[a]	Optimal frequency	Test stat.	Optimal frequency	Test stat.
lnCEI	1	−2.523	3	−2.061
lnCOV	2	−2.253	1	−2.620
lnGRSI	2	−2.581	1	−2.516
lnEPU	2	−1.920	1	−3.172
lnOILP	2	−1.874	2	−2.464
lnVIX	3	−2.407	3	−2.408
ΔlnCEI	3	−7.346*	3	−7.540*
ΔlnCOV	1	−9.432*	2	−9.845*
ΔlnGRSI	1	−14.337*	1	−14.334*
ΔlnEPU	2	−11.197*	1	−11.219*
ΔlnOILP	2	−9.165*	3	−9.247*
ΔlnVIX	3	−17.133*	3	−17.308*

Note: Critical values are obtained from E&L.
[a]Δ is the first difference operator.
*Indicates 1% statistical significance.

TABLE 4 The Tsong et al. (2016) cointegration test and the parameters

Panel A: Cointegration estimation through the FMOLS estimator			
Panel A1: Cointegration test[a,b]			
Frequency	Min. SSR	Test statistic	*F*-statistic
1	0.163	0.037	18.995*
Panel A2: Parameters			
Variable	Coefficient	Std. error	*t*-statistic
lnCOV	.009*	0.003	3.295
lnGRSI	.021***	0.012	1.760
lnEPU	−.082*	0.015	−5.554
lnOILP	.052**	0.023	2.272
lnVIX	−.144*	0.026	−5.458
Panel B: Cointegration estimation through the CCR estimator			
Panel B1: Cointegration test[a,b]			
Frequency	Min. SSR	Test statistic	*F*-statistic
1	0.164	0.035	17.275*
Panel B2: Parameters			
Variable	Coefficient	Std. error	*t*-statistic
lnCOV	.009*	0.003	3.329
lnGRSI	.021***	0.012	1.730
lnEPU	−.088*	0.017	−5.285
lnOILP	.051**	0.022	2.282
lnVIX	−.138*	0.027	−4.989

[a]Critical values are obtained from Tsong et al. (2016).
[b]SSR means the sum of squared residuals.
*Indicates 1% statistical significance.
**Indicates 5% statistical significance.
***Indicates 10% statistical significance.

4.1 | Discussion

The estimation results can provide five critical implications in terms of the firms and the policies. First, this paper reveals that the S&P500 CEI responded positively to the increase in COVID-19 cases. What could be the truth behind the fact that low-carbon companies are generally resilient to health shock, moreover, increasing stock returns? To answer this question, we underline that depositors/financial investor trust low-carbon companies more than companies in other sectors and can invest in the shares of such companies even during the health crisis period. Low-carbon companies appear as enterprises that use high-tech intensive production methods, adopt green technologies and green R&D investments and follow carbon footprint-calculation models. Such applications provide companies with a corporate image that is valued highly by investors (Ganda, 2018). Firms that maximise the combination of economic benefits, environmental benefits and social benefits follow a green financial management model that creates tremendous corporate value (Zhu et al., 2020). Investors invest in social responsibility status and corporate value in addition to the economic structure of companies. Many crises in history have shown that firms that have gained their customers' trust for their sustainable practices are more resilient to economic shocks. Firm-specific characteristics reveal that crises and epidemics also determine the effects those will have on firms. The market value of innovative businesses that adopt green technology is stable (Asadi et al., 2020; Przychodzen et al., 2020). These firms are competitive and more efficient (He et al., 2020; Nicola et al., 2020; Xiong et al., 2020). In short, companies that take sustainability criteria into account for their operation and development enjoy the advantage of having this reflected in their financial statements and market value in the long term.

Second, this research confirms the negative directional relationship between S&P500 CEI and the COEB VIX. Rising volatility in the stock markets hurts the S&P500 CEI. In other words, volatility in the markets negatively affects the stock returns of companies with lower carbon emissions. These findings are consistent with economic expectations. As a result of financial globalisation, international investors must consider the volatility of international financial markets in their investment decisions. Noteworthy is the fact that the CBOE VIX index is also called the fear index, emphasising that it reflects the tension created by the anxiety of investors and the perception of risk (Nicola et al., 2020; Salisu & Akanni, 2020; Sarwar & Khan, 2019; Shehzad, Xiaoxing, et al., 2021). Many studies in the literature show that the VIX index and important economic indicators, such as oil prices, exchange rates, consumer confidence index, gold-silver prices and interest rates, are in a close relationship (Badshah et al., 2018; Peng et al., 2019; Qadan & Yagil, 2012; Salisu et al., 2020; Zheng et al., 2017). The increase in the VIX index, which reflects the fear and panic in the market, bears repercussions for all sectors. Low-carbon company shares are also negatively affected by the increase in volatility in the markets. Third, we point out that the S&P500 CEI gives an adverse reaction to the increase in EPU. Like the CBOE VIX, there is an enormous amount of research in which is shown that the EPU negatively impacts many indicators, from stock markets to economic growth, employment, interest rates, commodity prices and inflation (Arouri et al., 2016; Xia et al., 2020).

Fourth, this paper finds evidence of a positive co-movement between oil prices and the S&P500 CEI. In other words, an increase in oil prices increases the low-carbon company share values. This result is especially critical in terms of combating climate change, one of the sustainable development goals. The oil price increase and supply disruptions experienced in the 1970s had a significant and long-term negative impact on economic activity worldwide. Many studies show that oil price increases harm the real economy and stock markets/financial markets (Basher et al., 2012; Hedi Arouri & Khuong Nguyen, 2010; Michieka & Gearhart, 2019; Papapetrou, 2001) because oil is the primary input for most industries. However, some sectors can benefit from the increase in oil prices. Managi and Okimoto (2013) cite the clean or alternative energy industry as the sectors that benefit from high oil prices. As oil prices increase, the demand of economic actors for alternative energy resources increases due to the substitution effect. This demand is reflected in demand for shares in clean and alternative energy companies.

Similarly, green and sustainable firms benefit from shocks associated with fossil energy prices, carbon prices and environmental regulations (Bushnell et al., 2009). In recent years, the increasing perception of the importance of sustainability has made companies more eager to invest in green technologies. Investors nowadays tend to create portfolios that include environmentally friendly companies. As companies produce and support environmentally friendly goods and services, they can attract more investments and increase the value of their shares. It is claimed that environmentally friendly companies have recently received significant interest from investors, policymakers and the community (Dutta et al., 2020). Therefore, considering the role of oil in global greenhouse gas emissions, it is possible to expect an increase in demand for low-carbon company shares. Several studies support the positive relationship between green firms and oil prices (Bondia et al., 2016; Managi & Okimoto, 2013; Nasreen et al., 2020). Therefore, low-carbon company shares can be regarded as an investment tool with high prospects and returns for investors.

Finally, we provide evidence that the overall government response index, which is the average of the stringency, containment health and economy indicators, positively affects the S&P500 CEI. A group of papers in the literature confirms that government lockdown policies have a short-term negative impact on stock returns and the real economy (Anh & Gan, 2020; Davis et al., 2021; Mandel & Veetil, 2020). On the other hand, there is evidence that health policies and economic incentives positively affect stock returns (Kizys et al., 2021; Rubbaniy et al., 2021; Zaremba et al., 2021). Health responses such as the government's vaccine research policies, case follow-up and quarantine practices reduce the number of new cases and reduce the pressure on the health system. All kinds of health practices that control the pandemic are expected to affect stock markets positively. Countries offer a variety of economic incentives and regulations to combat the economic effects of the epidemic. Many governments respond to debt delays, tax exemptions, low-interest loans, employment subsidies and increasing liquidity in the markets. The reflection of such government efforts on the stock market is expected to be positive.

The impact of overall government response on stocks differs depending on the sector. However, our knowledge about the impact of government responses on sustainable firm stocks during the COVID-19 pandemic is limited. Hence, this paper that focuses on the reaction of indices in the ESG family to government responses will contribute to filling the gap. Therefore, our empirical findings implying that low-carbon company shares are positively affected by the health, economy and lockdown policies implemented by the government during the COVID-19 pandemic have critical political implications explained above.

5 | CONCLUSION

This paper has examined the impact of the COVID-19 pandemic, EPU, oil prices, market volatility and government responses on the S&P500 CEI in the USA for daily data. We followed a time series method based on the Fourier approximation to capture both sharp and smooth breaks. The paper's findings can be summarised as follows: (1) S&P500 CEI is positively affected by the increase in COVID-19 confirmed cases. (2) EPU and global fears in the markets have adverse effects on the S&P500 CEI. (3) S&P500 CEI takes advantage of the increase in oil prices. (4) The S&P500 CEI is positively affected by the combination of government responses to stringency, containment health and economy.

Furthermore, this paper shows that low-carbon company stocks are resistant to health shocks and the subsequent rise in oil prices; moreover, share values increase. The Stock Exchanges rewards highly sustainable portfolios during the pandemic period. That is, low-carbon company shares provide a safe-haven status for stakeholders against health shocks. On the other hand, as in many other sectors, the green sector suffers from policy uncertainties and market volatility. Government responses to the pandemic favour green firms in safeguarding their share values. Hence, our findings provide important implications for the development of sustainable business models. Finally, while the literature primarily focuses on the dynamics affecting company shares in the food, industry, tourism, service, aviation and retail trade sectors, there is a gap in the literature about the factors affecting the stocks in the ESG family, which bear sustainability criteria. Future research can focus on the ESG family, examining the response of sustainable financing instruments to energy prices, crisis and health shocks and policy uncertainties. Researchers can examine whether the ESG family is a safe haven against cyclical shock. Its response to shocks is comparable to other financial instruments. New research can apply the ESG index family members to other industries. Indeed, this type of research will provide new information on low-carbon and alternative business models and contribute to the development of sustainable development policies and the formation of stable investment portfolios, particularly for sectors such as social security funds that require investments with certain returns.

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ENDNOTE

[1] See Tsong et al. (2016) for further details of the test.

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