The current issue and full text archive of this journal is available on Emerald Insight at:
https://www.emerald.com/insight/1859-0020.htm

COVID-19, clean energy stock market, interest rate, oil prices, volatility index, geopolitical risk nexus: evidence from quantile regression

Sudeshna Ghosh
Department of Economics, Scottish Church College, Kolkata, India

Received 24 April 2022
Revised 1 August 2022
13 August 2022
Accepted 17 August 2022

Abstract

Purpose – The outbreak and the spreading of the COVID-19 pandemic have impacted the global financial sector, including the alternative clean and renewable energy sector. This paper aims to assess the impact of the pandemic, COVID-19 on the stock market indices of the clean energy sector using quantile regression methods.

Design/methodology/approach – This study utilized daily data sets on the four major categories of stocks: (1) Morgan Stanley Capital International Global Alternative Energy Index, (2) WilderHill Clean Energy Index, (3) Renewable Energy Industrial Index (RENIXX) and (4) the S&P 500 Global Clean Index. The study adopts a multifactor capital asset pricing model.

Findings – Clean and alternative energy stocks are powerful instruments for diversification. However, the impact of the volatility index induced by infectious disease is negative and significant across quantiles.

Practical implications – For investors and policymakers, considering how the uncertainty caused by COVID-19 and the geopolitical index influences renewable energy markets is of great practical importance. For investors, it throws insights into portfolio diversification. For policy makers, it helps to devise strategies to reboot the economy along the lines of the deployment of renewables. This study sheds light on a global green-energy transition and has practical implications for renewable energy resilience in post-pandemic times.

Originality/value – This paper can be considered as a pioneer that explores the nexus between oil prices, interest rates, volatility index, and geopolitical risk upon the stock indices of clean and alternative sources of (renewable) energy in the COVID-19 pandemic situation. The results have important insights into the area of energy and policy decision-making. Additionally, the paper's novelty lies in using the explanatory variables associated with the Covid 19 pandemic.

Keywords Clean energy, Oil prices, Geopolitical index, COVID-19, Quantile regression

Paper type Research paper

1. Introduction

Since the confirmation of the first case on the coronavirus (COVID-19) as per records in the Wuhan province of China during December 2019, the contagion effect of the virus created devastations around the globe forcing the World Health Organization to declare a pandemic situation. According to Wang and Su (2020) and Wang *et al.* (2021a), major countries worldwide imposed restrictions on mobility, had closed down the borders, declared lockdown and other stringency measures to combat the health crisis. The main objective of this paper is to contribute to the extant seam of literature by exploring the drivers of clean and alternative energy stock at the backdrop of the pandemic COVID-19. The clean and alternative sources of

Journal of Economics and Development
Vol. 24 No. 4, 2022
pp. 329-344
Emerald Publishing Limited
e-ISSN: 2632-5330
p-ISSN: 1859-0020
DOI 10.1108/JED-04-2022-0073

(renewable) energy represents a significant position as far as the energy portfolio is concerned because it helps to reduce the dependence on fossil fuels and thus has climate welfare-enhancing implications.

In the recent years, clean energy has experienced rapid growth due to the environmental concerns and governmental policies toward clean energy (Apergis and Payne, 2014; Bondia *et al.*, 2016). Ample studies have discussed the importance of clean energy vis-a-vis the instability of the oil prices (Chien *et al.*, 2021; Ferrer *et al.*, 2018). Unarguably, there is scant discussion in the literature on the nexus between oil prices and clean energy due to the COVID-19 pandemic and the resilience of clean energy stocks, to meet the goals of the recently held climate talks in Glasgow (COP26). As capital investments get increasingly shifted toward clean energy sources, it is crucial for the investors to consider the risk consequences in the portfolio design and to make decisions on portfolio management. This is essential for long-term viability of investments in clean energy and benefit for the environment particularly against the backdrop of the pandemic. Early discussion in the literature documents the Granger causality between oil prices and clean energy stocks (Chowdhury *et al.*, 2021; Ahmad *et al.*, 2018; Sadorsky, 1999). The long-run dynamic dependence between clean energy and oil prices strengthens (Liu and Hamori, 2020; Khan *et al.*, 2017). The impact of crude oil prices on clean energy varies across quantiles, and there is stronger association during market downswings (Azimli, 2020). Likewise, volatility spill overs may be stronger between clean energy stocks and oil prices during periods of market turmoil (Chien *et al.*, 2021; Chowdhury *et al.*, 2021). In recent periods, a fistful of studies has discussed the impact of the COVID-19 pandemic on energy markets (Wan *et al.*, 2021; Hemrit and Benlagha, 2021). The empirical outcomes of these studies show the highest levels of market interconnectedness during the period of the pandemic.

Now the novel coronavirus COVID-19 has impacted the global financial markets severely. Market fear is commonly available in the volatility assessments. The volatility index (VIX) VIX index framed by the Chicago Board Options Exchange shows the significance of market volatility against the backdrop of the pandemic. Besides, the low interest rates during the pandemic can generate favorable conditions for clean energy investments. In addition to the financial conditions, geopolitical risk is a significant indicator of energy transition. Geopolitical risks create an atmosphere of uncertainty.

The clean energy sector unarguably is heavily impacted by the pandemic. Sharp downturns in economic activities have caused delays in financing the clean energy sector (Baker *et al.*, 2020). The reduction in the global energy demand due to lockdowns has a big toll on the energy investments. In the light of the above arguments and the debates in the international policy framework to promote clean energy, COVID-19 has introduced a high degree of uncertainty as well as economic and political implications. Further, to construct long-standing energy policies in view of the turbulent market conditions, it is important to scrutinize the major drivers of clean energy against the backdrop of the pandemic. Consequently, this study aims to reveal the important drivers of clean energy for energy transition to a more resilient energy system that could withstand the shocks from the pandemic and risks of future crises. In comparison to the earlier research, our study is the first to the best of our knowledge to explore the combined impact of uncertainty emanating from the pandemics and uncertainty owing to the geopolitical uncertainty on the clean energy indices, namely, (1) Morgan Stanley Capital International (MSCI) Global Alternative Energy Index, (2) WilderHill Clean Energy Index, (3) Renewable Energy Industrial Index (Renixx) and (4) the S&P 500 Global Clean Index (GCE). Although many studies have explored the effects of COVID-19 on clean energy returns, none of the earlier studies has combined the related uncertainties and fear gauge alongside oil prices and the rate of interest that can influence the clean energy stocks. We have adopted the quantile regression, which allows us to know whether extremely high or low changes originating from the pandemics and other factors lead to changes in the stocks of clean energy. The higher the degree of heterogeneity in the investor's beliefs, the more the price overvaluation. For this reason, to explore the heterogeneity in the outcome, quantile techniques are the most appropriate.

To this end, the current study aims to reconnoiter whether geopolitical risk (henceforth GPI) can impact uncertainty associated with cleaning energy stocks against the backdrop of the contagion effect of COVID-19. In doing so, we contribute to the literature in several aspects. First, to the best of our understanding, this is among the preliminary studies to examine the role of geopolitics on clean energy stocks. Given that oil prices are impacted by geopolitical tensions, intuitively speaking, geopolitical tensions are likely to impact the clean energy stocks because oil and clean energy stocks are highly correlated. In particular, geopolitical uncertainty may impact the clean energy stocks when it impacts the oil prices. Likewise, investors' expectations against the backdrop of geopolitical uncertainty may be influenced as they look for alternative perspectives (Chowdhury *et al.*, 2021; Wan *et al.*, 2021; Zaremba *et al.*, 2020). Second, variations in geopolitical risk impact the investor behavior, which may impact the interest rates leading to an energy transition to use of renewables.

Third, investigations between the clean energy–oil prices–VIX–pandemics–interest rate–GPI nexus are important, given that there may be varying responses across sectors. Proper knowledge of the varying responses is important for developing hedging strategies to mitigate the risks. Additionally, the empirical outcomes of the study could be used to throw insights into building forecast accuracy of these assets. The results have important insights into the area of energy and policy decision-making. In addition, the uniqueness of the paper lies in the use of the variables whose description is extensively associated with the COVID-19 pandemic. Assessing the impact of the pandemic on the stock prices of the clean and alternative (renewable) energy source is crucial from a policy perceptive, but it is also challenging because the contagion effect is changing with speed. We identified three indicators, namely, confirmed cases owing to COVID-19, human deaths and the newly constructed Baker *et al.* (2020) volatility index related to infectious diseases (EVs). The panic of the infection severely impacts business decisions; earlier studies in the literature rarely discuss how volatility index related to EVs impacts the stock prices of clean and alternative sources of (renewable) energy. The timeliness of the study is also unique in contrast to the earlier studies in energy modeling. The earlier data are measured on an annual basis, whereas this study has used daily observations for generating the scope of detailed analysis and enhancing the efficiency of model specification.

The paper henceforth is designed as follows: the next section discusses the major empirical findings in the literature; the subsequent next section outlines the research methodology and data sets. The empirical results and discussion are found in Section 4. Section 5 concludes the study.

2. Background literature

According to the studies by Fernandes (2020), Kim and Orlova (2021), and Gillingham *et al.* (2020), the pandemic has impacted global energy use, particularly due to the shutdown of major industries. The study by Chien *et al.* (2021), using the wavelet method, explored the nexus between pandemic, oil markets, stock prices, geopolitical risk and economic uncertainty for the countries of China, Europe and the USA The period of analysis runs from December 31, 2019 to August 1, 2020. The results demonstrate the severity of the impact of the pandemic on the productivity of the industrial sector. Further, the study obtained that there are co-movements in the prices of oil and the stock prices. The paper concluded with the need for proper policy implications so that investment decisions relating to the energy markets are taken in the right direction. Accordingly, Chowdhury *et al.* (2021), using quantile regression for the period 1996Q1 to 2020Q1 explored the impact of pandemics, global uncertainty and geopolitical risk on energy markets and stock markets in general. The study found that though the global uncertainty and the pandemic negatively impact the markets, there are substantial variations across the quantiles. In addition, the geopolitical risk also adversely impacts the markets. There exists unidirectional causality from world uncertainty, the incidence of pandemics and geopolitical risk to the energy and stock markets. The study concluded with the need for policy directions for proper investment management in the concerned sectors. Again, Wang *et al.* (2021a) deliberated on the devastations that the pandemic has caused in the real and financial sectors. Such impact of the pandemic has altered investors' portfolio diversification strategies toward solar stock prices. The study concluded with the need for government intervention to encourage the use of solar energy for sustainable development. A recent study by Ghabri *et al.* (2021) explores the nexus between fossil energy prices and clean and renewable energy prices over the time from March 10, 2020 to June 15, 2020. The study based on a time-varying vector autoregressive (VAR) VAR model obtained the negative association between prices of fossil energy and renewable energy prices. The paper urged the governments to suggest suitable prescriptions for investment in the renewable energy markets.

Based on the above milieu, we find that the enormous impact of COVID-19 and the concomitant shocks presents a need for revisiting the nexus between the impacts of the pandemic and the clean energy markets. There is a lack of dominance of findings in the literature on the impact of COVID-19 on the clean energy sector in the extant discussion in the literature. In this paper, we explore the unprecedented impact of COVID-19 on the clean energy sector. Thus, we frame the first testable hypothesis of the study:

H1. COVID-19 impacts the renewable energy stock prices.

The study by Wan *et al.* (2021) discussed that COVID-19 has a significant adverse impact on the financial and energy stock markets. However, the pandemic has positively impacted the returns of clean energy stocks. The study emphasized the role of the investors' attention toward clean energy stocks as an alternative source of investments. The paper concluded with the need for the government policies to promote the implementation of green technology, particularly in the post-pandemic situation. Again, Wang *et al.* (2021b), based on panel studies related to China, discussed the recent pandemic's role in reducing greenhouse gas emissions. The study concluded that further research explorations are necessary to establish the environmental welfare impact of the pandemic. According to Hoang *et al.* (2021), there is an urgent need for policymakers across countries to identify the trajectory toward the adoption of green technology, particularly in the post-pandemic period. Alternatively, Hemrit and Benlagha (2021) using daily observations from January 3, 2005 to June 30, 2020, examined how the global pandemic and the economic policy uncertainty impact the renewable energy index. The results based on the quantile regression demonstrated that the global pandemic significantly and positively impacted the renewable energy index, while the economic policy uncertainty adversely affected the renewable energy index. The paper suggested that the particular challenges owing to the pandemic can be converted to unique policy propositions, which would generate opportunities for investors to procure the benefits of investment in the renewable energy stock market. A strand in the literature, for instance (Dutta *et al.*, 2019; Kahneman and Tversky, 2013; Kumar, 2017; Kouton, 2019), claims that empirical findings based on the linear model specification could be erroneous owing to high volatility in the time series on financial variables. The study by Kahneman and Tversky (2013) stressed the importance of asymmetric modeling building exercises. Economic and financial variables may exhibit non-linearity owing to uncertainty and crisis (Kouton, 2019). Thus, non-linear model specification is particularly suitable for capturing the co-movements in financial variables. Addressing these ongoing deliberations in the extant literature, we frame the second testable hypothesis of the study as follows:

H2. COVID-19 has a non-linear impact on renewable energy stock prices.

The discussion in the extant strand concluded that the stock prices and the prices of energy stocks particularly are crucially impacted by uncertainty emanating from the contagion of COVID-19, geopolitical risk and the movement of oil prices. The studies are ambiguous on the recuperative behavior of the oil prices and its implications on the prices of renewable energy stock. Further, the literature has obtained mixed findings on the impact of the pandemic on renewable energy prices. Such obstruse findings from the literature renew the scope of exploration of the nexus between the COVID-19 contagion, renewable energy prices, oil prices, uncertainty and geopolitical risks. There is a growing need to understand the importance of clean energy use against the backdrop of socio-economic performance. This research is the first of its kind that explores the moderating impact of geopolitical risk in an integrated framework of the COVID 19 uncertainty, oil prices, energy prices and renewable energy prices. The extant literature has failed to investigate the moderating impact of geopolitical risk on the pandemic uncertainty and its impact on renewable stock prices (Xie *et al.*, 2021). Such exercises will help to broaden the scope of the policy implications on the path of recovery in the post-pandemic situation and reforms on investment in renewable energy stocks.

According to the review of the extant literature, the impact of the GPI on clean energy is debatable. These contentious shades of findings have renewed ample discussion in the scholarly literature using various samples and diverse methodological tools. However, the earlier works mostly focused on the direct impacts of the geopolitical risks on the volatility of the clean energy sector. The indirect impacts through channels of COVID-19 are largely ignored. In the commonly used asset pricing model behavior, this research proposes a new mechanism to investigate the moderating impact of GPI. In addition, according to the statistical theory, a moderation occurs when two variables interact in such a way as to include the moderating role. This research adds to the ongoing deliberations in the clean energy stocks–pandemic–geopolitical risk nexus by creating the interaction term. Accordingly, the third testable hypothesis of the study is proposed as follows:

H3. Geopolitical risk significantly aggravates the impact of COVID-19 on renewable energy stocks.

3. Research methodology and data sets

Our empirical design explores the performance of stocks of clean energy that differ from industries affected by carbon intensity. The methodological approach of this study can be described in two stages: first, the approach that examines the abnormal return during the pandemic, and second, that determines the cross-section components of the abnormal return. The underlying assumption of our study is that markets are efficient, the occurrence of events is not anticipated and timing is exogenously set. COVID-19 is an unanticipated occurrence that enables us to assess how the stocks of clean energy markets' values fluctuate under different contexts of uncertainties. To determine the stock pricing behavior, a normal return of the stock before the occurrence of the unanticipated event needs to be established. This is explained as the difference between the normal return and firm's actual return during the period of the event.

3.1 Model

This study attempts to explore the influence of the recent COVID-19 pandemic on the stock prices of clean and alternative sources of (renewable) energy. Further, the impact of oil prices, interest rate, volatility index and geopolitical index (GPI) is used as a control to overcome the problems of endogeneity.

$$R_t = \alpha_1 + \beta_M R_{Mt} + e_t \tag{1}$$

The excess return on the stock is denoted by R_t; the excess market return on the stock is expressed through R_{Mt}, the intercept term is α, the coefficient is denoted by β and the error term is denoted by e. Equation (1) explains the excess return to the stock, which is affected by the excess return of the market R_{Mt}, and the coefficient β_M, which is a measure of the sensitivity of the stock in the market. Further, equation (2) discusses the excess return on stock in a multivariate framework following the earlier literature (Bodie *et al.*, 2010; Zaremba *et al.*, 2020).

$$R_t = \alpha_1 + \beta_M R_{Mt} + \beta_1 COVID_t + \beta_2 VIX_t + \beta_3 OIL_t + \beta_4 INT_t + \beta_5 GPI_t + \beta_6\, GPI_t * COVID_t + e_t \tag{2}$$

where $t = 1,2 \ldots$T; R_t indicates the daily excess return of the stock price of clean and alternative sources of (renewable) energy; R_{Mt} shows the daily excess market return, which could be the drivers of the stock prices of clean and alternative sources of (renewable) energy. This study attempts to use the S&P 500 GCE as the driver (excess market return), which is expected to have a positive impact. e_t is the usual error term. $COVID_t$ denotes the impact of the pandemic that specifies the impact of the daily confirmed cases, incidence of daily deaths and the recently postulated Baker *et al.* (2020) volatility index associated with EVs. We argue following the recent studies in the literature, for example (Wan *et al.*, 2021; Wang and Su, 2020), that the disruptive forces of the pandemic have moved the investors' attention toward the potential for a recovery in green energy so that it will attract more investments. Our supposition now needs further empirical verification. VIX_t denotes the daily volatility index of the Chicago Board. According to Mishra and Mishra (2020), a rise in VIX_t has negative implications for stock prices. OIL_t denotes the oil price index. A growing number of studies see Ferrer *et al.*, (2018) and Khan *et al.* (2017) discussing that the price of oil and renewable move in the same direction. INT_t denotes the rate of interest. According to the study by Sadorsky (1999), alternative energy prices are very sensitive to business cycles. We argue that during the expansionary period of economic growth, rising interest rates imply that the investors are willing to invest in sectors that are benefitted from economic growth. However, there may be variations during the economic slowdown due to the pandemic's uncertainty. GPI_t is the GPI. The inclusion of GPI is remarkably important because it exposes the investors to a position of destabilization. The impact of GPI on the stock market dynamics has increasingly received scholarly attention in the recent decade, e.g., Bouri *et al.* (2019) and Caladara and Iacoviello (2018). It is expected that the moderating role of the GPI will not impact the market dynamics uniformly.

3.2 Methodology

This study adopted the QR methodology postulated by Koenker and Bassett (1978) to explore the impact of COVID-19 on clean and alternative stock prices controlling macro-economic variables and GPI. According to Azimli (2020), since the ordinary least squares estimation does not reflect the estimation changes at the tail ends, it may generate spurious results. The adoption of the quantile estimation techniques will generate robust and consistent estimation (Azimli, 2020).

Equation (3) demonstrates the conditional quantile function for empirical estimation of the model under equation (2):

$$Q_y(\varnothing|x) = \inf\{\partial|F_y(\partial|x) \geq \varnothing\} = \sum_h \beta_h(\varnothing)x_h = x\beta(\varnothing) \tag{3}$$

The conditional distributing function for given x on y is explained by $F_y(\partial|x)$. The quantile regression coefficient $\beta(\varnothing)$ explains the dependency across Vector X and $\varnothing$th conditional quantile on y. This study examines how the impact of the explanatory variables impacts across the quantiles. If the impact across quantiles is fixed, it is a constant configuration; if they decline, then the configuration is explained to be a declining one, and it is asymmetrically impacting if the impact varies across the lower and higher quantiles.

3.3 Data description

We use daily frequency observations from December 31, 2019 to December 30, 2020. We have 365 observations. Since the earliest incidence of cases of the COVID-19 pandemic was found in December 2019, our sample observations begin from December 31, 2019. We have used three global renewable energy indices as the dependent variable in the model. They are as follows: (1) the Renewable Energy Industrial Index (RENIXX), 2) WilderHill Clean Energy Index and (3) MSCI Global Alternative Energy Index. Further, the study has used the daily frequency observations on S&P 500 GCE as a driver to clean energy prices. The data on renewable energy stocks are available on Bloomberg, Wall Street Online and DataStream. It is important to note that during the recent COVID-19 pandemic, the MSCI, RENIXX and WilderHill Clean Energy Index were thoroughly interconnected, which demonstrates the central role in connecting the clean energy indicators (Ghabri *et al.*, 2021; Wang *et al.*, 2021a).

The data on COVID-19 cases and death rates are available from the GitHub website provided by Johns Hopkins University Center. Data on volatility index associated with the EVs tracker are obtained on FRED. Further, the data on the volatility index of the Chicago Board are also obtained from FRED.

Data on oil prices are available on Brent crude oil prices online. It is well documented that the oil prices fell to a negative low US$37.63/barrel on April 20, 2020, due to the contagion effect of COVID-19. Crude oil is considered a major energy source in the global context (Bondia *et al.*, 2016; Wang *et al.*, 2021a). The crude oil market is intricately linked with other markets. A wide-ranging discussion explains how oil prices impact major markets (Khan *et al.*, 2017; Ferrer *et al.*, 2018).

Interest rate data are obtained on FRED. To boot recovery in the economy, governments of all major nations introduced large stimuli. Besides, interest rates were also kept at low levels as a precursor of the expansionary monetary policy. In addition, low interest rates can provide the appropriate momentum to develop clean energy projects. The data on the GPI is available from Caldara and Iacoviello (2018). As postulated by Caldara and Iacoviello (2018), the GPI is available at https://www.matteoiacoviello.com/gpr.htm. It is based on text mining of important dailies, which covering geopolitical tensions. The descriptive statistics for the variables are reported in Table 1.

4. Results and discussion

4.1 Empirical results

Table 2 reports the quantile regression estimation of the impact of pandemics on the clean energy stocks, namely, RENIXX. Based on the results of (Model I), we find that the incidence of COVID-19 cases has a negative impact upon the lower quantiles but a positive impact on the upper quantiles. The results are statistically significant. Further, the impact of death rates owing to COVID-19 also shows asymmetric behavior (Model II). The results are statistically significant. The results indicate that the market is pessimistic under a bearish situation, but it

Table 1.
Descriptive statistics

	MSCI	SP	Oil	Interest	Cases	GPI	VIX	RENIXX	WilderHill	EV	Deaths
Mean	3.05	3.05	1.61	0.29	2.75	1.89	1.41	2.96	1.74	1.16	1.58
Median	3.05	3.02	1.62	0.11	3.07	1.87	1.39	2.91	1.69	1.28	1.85
Max	3.13	3.28	1.80	1.56	3.90	2.43	1.91	3.20	3.16	2.05	2.27
Min	2.82	2.82	0.94	−0.05	0.07	1.39	1.08	2.70	1.35	−0.07	0.02
Standard deviation	0.06	0.11	0.14	0.48	0.96	0.22	0.15	0.12	0.24	0.49	0.68
Skewness	0.79	0.34	−0.162	2.07	−0.92	0.33	0.53	0.31	0.88	−1.19	−1.14
Kurtosis	2.86	2.11	5.95	5.43	2.84	2.06	4.10	2.00	4.88	3.77	2.95

Source(s): Author compilation

is optimistic under a bullish situation. The results based on (Models I and II) confirm H1 and H2 of our study. However, the impact of the volatility index induced by EV is negative and significant across quantiles. These results based on Model III do not confirm H1 and H2 of our study.

Table 3 reports the quantile regression estimation of the impact of pandemics on the clean energy stocks, namely, WilderHill. Based on Table 3, the results of (Model I) show a positive impact of the incidence of COVID-19 cases across all quantiles. These results confirm H1 of our study. Regarding the impact of EV on the WilderHill index, the impact is positive across all quantiles, except at Q0.50 and Q0.60. The findings are statistically significant. The results confirm H1 of our study. As far as the impact of EV upon the WilderHill index is concerned, it is positive at the lower quantiles but negative at the upper quantiles. These results confirm H2 of our study.

Table 4 presents the quantile regression results of the impact of the pandemics on the clean energy stock, namely, MSCI stocks. The impact of COVID-19 cases and deaths is positive and statistically significant across all quantiles (Models I and II, respectively), thereby confirming HH1. The impact of EV on the MSCI stocks is asymmetric; it is negative at the lower quantiles and positive at the upper quantiles. The results are statistically significant. The results confirm H2.

Altogether, the results demonstrate that the crisis owing to the pandemic has led to the diversification of funds by investors. The clean and alternative energy stocks are significant instruments for diversification. The findings in conformity with the study by Wang and Su (2020) and Wan *et al.* (2021) demonstrate the severity of financial uncertainty owing to the pandemic and raise apprehension about the transition to green energy.

As far as the control variables are concerned, the impact of S&P stocks upon other clean energy stocks is positive per expectations. It is a major driver in the market. There is evidence of co-movements between the price of oil and clean energy stocks across all the markets, see Tables 2–4). Such findings confirm the studies by Ferrer *et al.* (2018) and Apergis and Payne (2014). Confirming the earlier studies (Ahmad *et al.*, 2018; Liu and Hamori, 2020), there are co-movements between the price of clean stocks and the VIX. The findings indicate that VIX, a proxy for financial uncertainty, has a spillover effect on the investors' market expectations. Following the earlier studies, e.g., Moya-Martínez *et al.* (2015) and Bondia *et al.* (2016), the study obtains that interest rates play a crucial role in explaining the variations in stock prices of clean energy. There is a negative association between interest rate and the prices of clean stocks. Interest rates have a crucial bearing in the "investors' decision-making" and hence the functioning of the stocks particularly the green stocks.

The impact of the GPI on clean energy stocks is negative across all stocks (Tables 2–4). The results suggest that investors' sentiment declines during periods of higher political and social tensions, as demonstrated through the geopolitical risk index. However, the

Table 2. Impact of COVID-19 on stock prices of alternative energy use (RENIXX stocks)

Dependent variable RENIXX						Model I					
Variable	Q5	Q10	Q20	Q30	Q40	Q50	Q60	Q70	Q80	Q90	Q95
S&P stocks	0.89** (0.00)	0.93** (0.00)	0.92** (0.00)	0.95** (0.00	0.97** (0.00)	0.98** (0.00)	1.00* (0.00)	1.02* (0.00)	1.02* (0.00)	1.04* (0.00)	1.004* (0.00)
Oil	0.15** (0.00)	0.10** (0.00)	0.10** (0.00)	0.10** (0.00)	0.07** (0.00)	0.05** (0.03)	0.02 (0.26)	0.02** (0.00)	0.01** (0.39)	0.01 (0.40)	0.02 (0.19)
Interest rate	−0.05* (0.00)	−0.04* (0.00)	−0.04* (0.00)	−0.03** (0.00	−0.03** (0.00)	−0.02** (0.00)	−0.07** (0.00)	−0.02* (0.00)	−0.02** (0.00)	−0.02** (0.001)	−0.04** (0.001)
GPI	−0.01 (0.14)	−0.15 (0.18)	−0.004 (0.75)	0.03 (0.86)	0.009** (0.002)	0.006** (0.001)	0.002** (0.001)	0.004** (0.79)	0.03* (0.00)	−0.03* (0.001)	−0.02* (0.01)
COVID-19 cases	−0.07 (0.49)	−0.01 (0.22)	−0.01** (0.01)	−0.02* (0.010	0.01* (0.00)	0.01* (0.002)	0.012* (0.002)	0.006* (0.05)	0.011* (0.00)	0.01* (0.001)	0.01* (0.00)
GPI * COVID-19 cases	0.01** (0.03)	0.06** (0.00)	0.02* (0.006)	0.02** (0.01)	0.001** (0.00)	0.05 (0.41)	0.02 (0.68)	−0.008 (0.90)	−0.003** (0.001)	−0.03** (0.01)	−0.003** (0.001)
VIX	0.004 (0.88)	−0.01 (0.62)	0.11 (0.56)	0.04** (0.00)	0.02** (0.08)	0.02** (0.06)	0.02* (0.02)	0.01 (0.19)	0.01 (0.49)	0.02* (0.03)	0.01* (0.002)
Constant	−0.02 (0.81)	−0.02 (0.78)	−0.06 (0.37]	−0.18* (0.00)	−0.16* (0.00)	−0.19* (0.00)	−0.20* (0.00)	−0.16* (0.001)	−0.20* (0.00)	−0.18* (0.01)	−0.19* (0.001)
Pseudo R^2	0.85	0.86	0.86	0.87	0.88	0.89	0.90	0.87	0.89	0.86	0.88

Dependent variable RENIXX						Model II					
Variable	Q5	Q10	Q20	Q30	Q40	Q50	Q60	Q70	Q80	Q90	Q95
S&P stocks	0.89** (0.00)	0.91** (0.00)	0.92** (0.00)	0.94** (0.00)	0.96** (0.00)	0.96* (0.00)	0.97* (0.00)	0.99* (0.00)	1.00* (0.00)	1.00* (0.00)	1.03* (0.00)
Oil	0.15** (0.01)	0.09** (0.02)	0.07** (0.00)	0.06** (0.03)	0.02 (0.38)	0.01 (0.43)	0.02* (0.31)	0.02 (0.89)	0.03 (0.80)	−0.02 (0.88)	0.01 (0.51)
Interest rate	−0.05** (0.03)	−0.02 (0.18)	0.02 (0.81)	−0.001 (0.51)	−0.01 (0.87)	0.03 (0.66)	−0.002 (0.97)	−0.05 (0.54)	−0.06 (0.58)	−0.001 (0.99)	−0.02 (0.17)
GPI	−0.01 (0.08)	−0.09 (0.35)	−0.01 (0.25)	−0.01 (0.89)	−0.00 (0.97)	−0.01 (0.59)	−0.03 (0.79)	−0.07 (0.45)	−0.07 (0.94)	−0.01 (0.15)	−0.01** (0.05)
COVID-19 deaths	−0.01 (0.54)	0.04 (0.79)	0.02** (0.06)	0.03** (0.02)	0.03** (0.00)	0.03** (0.004)	0.03** (0.02)	0.02** (0.09)	0.02** (0.006)	0.02** (0.01)	0.02** (0.00)
GPI * COVID-19 deaths	0.07* (0.01)	0.06 (0.27)	0.04 (0.38)	0.01 (0.73)	0.003* (0.00)	0.01* (0.001)	0.02* (0.007)	−0.01* (0.001)	−0.001* (0.001)	−0.007* (0.001)	−0.06* (0.01)
VIX	0.02 (0.99)	0.009 (0.76)	−0.04** (0.01)	0.03** (0.00)	0.03* (0.002)	0.03* (0.004)	0.03* (0.002)	0.02* (0.00)	0.03* (0.14)	0.05* (0.05)	0.03 (0.12)
Constant	−0.05 (0.95)	−0.03 (0.61)	−0.09 (0.14)	−0.10* (0.03)	−0.12* (0.001)	−0.09* (0.01)	−0.13* (0.00)	−0.13* (0.002)	−0.18 (−0.20)	−0.16* (0.03)	−0.22* (0.00)
Pseudo R^2	0.85	0.86	0.87	0.88	0.89	0.90	0.90	0.90	0.88	0.89	0.89

Dependent variable RENIXX						Model III					
Variable	Q5	Q10	Q20	Q30	Q40	Q50	Q60	Q70	Q80	Q90	Q95
S&P stocks	0.89** (0.00)	0.92** (0.00)	0.92** (0.00)	0.95** (0.00)	0.96** (0.00)	0.69** (0.00)	0.99** (0.00)	1.00** (0.00)	1.01** (0.00)	1.03** (0.00)	1.02** (0.00)
Oil	0.15* (0.00)	0.10* (0.01)	0.11* (0.00)	0.10* (0.00)	0.10* (0.01)	0.05* (0.02)	0.05* (0.02)	0.03 (0.13)	0.01 (0.23)	0.09 (0.56)	0.02 (0.24)
Interest rate	−0.05* (0.00)	−0.05* (0.00)	−0.04* (0.00)	−0.04** (0.00)	−0.03* (0.00)	−0.03* (0.00)	−0.02* (0.00)	−0.03* (0.00)	−0.03* (0.00)	−0.03* (0.00)	−0.03* (0.00)
GPI	−0.01** (0.01)	−0.09** (0.00)	−0.01 (0.29)	−0.01* (0.01)	−0.02** (0.05)	−0.03** (0.04)	−0.01** (0.02)	−0.01** (0.0016)	−0.03** (0.00)	−0.02** (0.05)	−0.24** (0.00)
EV	−0.02 (0.19)	−0.01 (0.28)	−0.01 (0.91)	−0.11** (0.002)	−0.02 (0.11)	−0.03** (0.001)	−0.06 (0.76)	−0.01 (0.42)	−0.01** (0.01)	−0.02** (0.02)	−0.02** (0.04)
GPI * EV	−0.01* (0.01)	−0.07* (0.01)	−0.08* (0.01)	−0.32* (0.00)	−0.13* (0.04)	−0.11* (0.001)	−0.05* (0.00)	−0.01* (0.001)	−0.02* (0.00)	−0.01* (0.00)	−0.11* (0.00)
VIX	−0.04 (0.89)	−0.02 (0.89)	−0.02* (0.001)	0.02* (0.07)	0.03* (0.02)	−0.03** (0.04)	0.03** (0.06)	0.01** (0.05)	−0.04 (0.78)	0.02 (0.08)	0.91 (0.33)
Pseudo R^2	0.85	0.85	0.86	0.87	0.88	0.89	0.89	0.89	0.89	0.88	0.88

Note(s): Figures in the parenthesis are p-values. (*), (**) and (***) denote the level of significance of 1, 5 and 10%, respectively. QR denotes quantile regression
Source(s): Compilation author

Table 3.
Impact of COVID-19 on stock prices of alternative energy use (WilderHill stocks)

Dependent variable WilderHill						Model I					
Variable	Q5	Q10	Q20	Q30	Q40	Q50	Q60	Q70	Q80	Q90	Q95
S&P stocks	1.60** (0.00)	1.59** (0.00)	1.58** (0.00)	1.65** (0.00)	1.68** (0.00)	1.71** (0.00)	1.70** (0.00)	1.73** (0.00)	1.72** (0.00)	1.77** (0.00)	1.76** (0.00)
Oil	0.09 (0.42)	0.11 (0.14)	0.16* (0.02)	0.15* (0.01)	0.15* (0.00)	0.11* (0.01)	0.10* (0.00)	0.06 (0.17)	0.06 (0.22)	0.07 (0.09)	0.08 (0.11)
Interest rate	−0.10* (0.00)	−0.09* (0.00)	−0.08* (0.00)	−0.07* (0.00)	−0.07* (0.00)	−0.07* (0.00)	−0.07* (0.00)	−0.07* (0.00)	−0.05* (0.00)	−0.02* (0.06)	−0.02 (0.20)
GPI	0.03 (0.60)	0.01 (0.60)	0.01 (0.62)	0.02 (0.89)	−0.01 (0.90)	0.04** (0.01)	0.04** (0.001)	0.17** (0.00)	0.14** (0.00)	0.02 (0.32)	0.01 (0.31)
COVID-19 cases	0.01* (0.01)	0.02* (0.02)	0.02* (0.01)	0.04* (0.00)	0.02* (0.02)	0.03* (0.004)	0.04* (0.00)	0.04* (0.00)	0.05* (0.00)	0.06* (0.00)	0.07* (0.00)
GPI * COVID-19 cases	−0.02 (0.72)	−0.05 (0.30)	−0.004 (0.48)	−0.10* (0.06)	0.01* (0.01)	0.003** (0.01)	0.02* (0.01)	0.02* (0.00)	0.05* (0.00)	0.07* (0.00)	−0.09* (0.01)
VIX	0.30** (0.00)	−0.09** (0.00)	−0.03** (0.00)	−0.03** (0.00)	−0.04** (0.00)	−0.07** (0.00)	−0.08** (0.00)	−0.08** (0.00)	−0.06** (0.00)	0.03 (0.47)	0.03 (0.47)
Constant	0.032 (0.68)	0.04 (0.15)	0.01** (0.00)	0.06** (0.00)	0.35** (0.00)	0.35** (0.00)	0.47** (0.00)	0.40** (0.00)	0.35** (0.00)	0.31** (0.00)	0.39** (0.00)
Pseudo R^2	0.75	0.76	0.78	0.80	0.81	0.82	0.83	0.83	0.82	0.78	0.72

Dependent Variable Wilder Hill						Model II					
Variable	Q5	Q10	Q20	Q30	Q40	Q50	Q60	Q70	Q80	Q90	Q95
S&P stocks	1.42* (0.00)	1.44* (0.00)	1.53* (0.00)	1.63* (0.00)	1.68* (0.00)	1.67* (0.00)	1.68* (0.00)	1.64* (0.00)	1.65* (0.00)	1.70* (0.00)	1.61* (0.00)
Oil	0.27** (0.03)	0.23** (0.01)	0.13** (0.03)	0.12** (0.03)	0.08 (0.06)	0.10* (0.01)	0.05* (0.01)	0.04 (0.29)	0.06 (0.09)	0.03 (0.43)	0.06 (0.31)
Interest rate	−0.01 (0.55)	−0.04 (0.15)	−0.05** (0.01)	−0.07** (0.00)	−0.06** (0.00)	−0.06** (0.00)	−0.03** (0.02)	−0.03 (0.12)	−0.07 (0.77)	0.04 (0.90)	−0.06 (0.89)
GPI	−0.01 (0.60)	−0.01 (0.56)	−0.03* (0.01)	−0.03** (0.00)	−0.04** (0.04)	−0.05** (0.00.)	−0.02** (0.00)	−0.03** (0.00)	−0.01 (0.48)	−0.01 (0.49)	−0.01 (0.56)
COVID-19 deaths	0.08 (0.08)	0.05 (0.17)	0.02* (0.01)	0.02* (0.00)	−0.01* (0.00)	−0.01* (0.00)	−0.04* (0.00)	−0.05* (0.00)	0.11* (0.010)	0.09* (0.00)	0.12* (0.00)
GPI * COVID-19 deaths	0.01 (0.98)	0.02 (0.90)	0.01* (0.003)	0.006* (0.00)	0.02* (0.01)	0.03* (0.01)	0.01* (0.00)	0.01* (0.00)	−0.06 (0.72)	−0.01 (0.88)	−0.01 (0.35)
VIX	−0.02 (0.67)	−0.05 (0.23)	−0.02** (0.00)	−0.04** (0.00)	−0.05** (0.02)	−0.04** (0.01)	−0.03 (0.24)	−0.06 (0.12)	0.01 (0.73)	0.02 (0.56)	0.01 (0.76)
Constant	−0.31** (0.00)	−0.31** (0.00)	−0.314** (0.00)	−0.37** (0.00)	−0.34** (0.00)	−0.34** (0.00)	−0.35** (0.00)	−0.31** (0.00)	−0.36** (0.00)	−0.32** (0.00)	−0.39** (0.00)
Pseudo R^2	0.76	0.77	0.78	0.79	0.81	0.82	0.83	0.83	0.82	0.77	0.71

Dependent variable WilderHill						Model III					
Variable	Q5	Q10	Q20	Q30	Q40	Q50	Q60	Q70	Q80	Q90	Q95
S&P stocks	1.59* (0.00)	1.55* (0.00)	1.62* (0.00)	1.65* (0.00)	1.72* (0.00)	1.70* (0.00)	1.74* (0.00)	1.73* (0.00)	1.70* (0.00)	1.77* (0.00)	1.79* (0.00)
Oil	0.13 (0.10)	0.18** (0.00)	0.21** (0.00)	0.20** (0.00)	0.19** (0.00)	0.19** (0.00)	0.15** (0.00)	0.13** (0.00)	0.15** (0.00)	0.16** (0.03)	0.09** (0.24)
Interest rate	−0.09* (0.00)	−0.10* (0.00)	−0.10* (0.00)	−0.10* (0.00)	−0.10* (0.00)	−0.11* (0.00)	−0.11* (0.00)	−0.13* (0.00)	−0.13* (0.00)	−0.12* (0.00)	−0.13* (0.00)
GPI	−0.04 (0.23)	−0.04 (0.16)	−0.04 (0.16)	−0.06** (0.00)	−0.06** (0.00)	−0.07** (0.00)	−0.05** (0.03)	−0.03** (0.03)	−0.02** (0.03)	−0.06** (0.04)	−0.05 (0.17)
EV	0.01 (0.98)	0.05 (0.90)	−0.02* (0.04)	−0.03* (0.03)	−0.07* (0.00)	−0.07* (0.03)	−0.05* (0.04)	−0.03* (0.00)	−0.01* (0.00)	−0.05* (0.00)	−0.02 (0.71)
GPI * EV	0.01 (0.71)	0.01 (0.69)	0.02** (0.00)	0.03** (0.00)	0.05** (0.01)	0.05** (0.002)	0.04** (0.03)	0.02** (0.00)	0.02** (0.00)	0.03** (0.0)	0.01 (0.64)
VIX	−0.08** (0.00)	−0.07** (0.00)	−0.07** (0.00)	−0.04** (0.00)	−0.07** (0.00)	−0.06** (0.002)	−0.09** (0.00)	−0.13** (0.00)	−0.13** 0.00)	−0.07** (0.00)	−0.14 (0.10)
Constant	−0.03* (0.00)	−0.03* (0.00)	−0.03* (0.00)	−0.04* (0.00)	−0.04* (0.00)	−0.04* (0.00)	−0.05* (0.00)	−0.03* (0.00)	−0.04* (0.00)	−0.07* (0.00	−0.07* (0.00)
Pseudo R^2	0.76	0.77	0.78	0.79	0.80	0.82	0.82	0.82	0.81	0.76	0.69

Note(s): Figures in the parenthesis are p values. (*), (**) and (***) denote the level of significance of 1, 5 and 10%, respectively. QR denotes quantile regression
Source(s): Compilation author

Table 4. Impact of COVID-19 on stock prices of alternative energy use (MSCI stocks)

Dependent variable MSCI						Model I					
Variables	Q5	Q10	Q20	Q30	Q40	Q50	Q60	Q70	Q80	Q90	Q95
S&P stocks	0.39** (0.00)	0.38** (0.00)	0.42** (0.00)	0.42** (0.00)	0.43** (0.00)	0.48** (0.00)	0.49** (0.00)	0.49** (0.00)	0.50** (0.00)	0.47** (0.00)	0.50** (0.00)
Oil	0.28* (0.00)	0.23* (0.00)	0.15* (0.00)	0.16* (0.00)	0.12* (0.00)	0.12* (0.00)	0.11* (0.00)	0.13* (0.00)	0.11* (0.00)	0.11* (0.04)	0.15* (0.04)
Interest rate	−0.08* (0.00)	−0.08* (0.00)	−0.09* (0.00)	−0.09* (0.00)	−0.09* (0.00)	−0.11* (0.00)	−0.12* (0.00)	−0.12* (0.00)	−0.11* (0.00)	−0.13* (0.00)	−0.13* (0.00)
GPI	−0.01 (0.97)	−0.02 (0.89)	−0.03** (0.01)	−0.01** (0.00)	−0.01** (0.00)	−0.09** (0.00)	−0.09** (0.00)	−0.11** (0.00)	−0.11** (0.00)	−0.12** (0.00)	−0.11 (0.70)
COVID-19 cases	0.01 (0.43)	0.01 (0.46)	0.07** (0.01)	0.07** (0.00)	0.04** (0.00)	0.07** (0.00)	0.07** (0.00)	0.09** (0.00)	0.11** (0.00)	0.12** (0.00)	0.16** (0.04)
GPI * COVID-19 cases	0.03 (0.49)	0.03 (0.77)	0.03* (0.01)	0.03* (0.01)	0.03* (0.00)	0.04* (0.00)	0.09* (0.00)	0.05* (0.00)	0.07* (0.00)	0.08* (0.00)	0.02 (0.30)
VIX	0.07** (0.01)	0.06** (0.00)	0.06** (0.01)	0.09** (0.00)	0.11** (0.04)	0.22** (0.00)	0.24** (0.00)	0.28** (0.00)	0.25** (0.00)	0.30** (0.00)	0.34** (0.00)
Constant	1.21** (0.00)	1.31** (0.00)	1.35** (0.00)	1.33** (0.00)	1.33** (0.00)	1.02** (0.00)	0.96** (0.00	0.90** (0.00)	0.99** (0.00)	0.95** (0.00)	0.74** (0.00)
R^2 pseudo	0.71	0.69	0.68	0.67	0.66	0.65	0.62	0.57	0.51	0.44	0.39
Dependent variable MSCI						Model II					
Variable	Q5	Q10	Q20	Q30	Q40	Q50	Q60	Q70	Q80	Q90	Q95
S&P stocks	0.37* (0.00)	0.35* (0.00)	0.38* (0.00)	0.41* (0.00)	0.44* (0.00)	0.49* (0.00)	0.51* (0.00)	0.50* (0.00)	0.51* (0.00)	0.48* (0.00)	0.47* (0.00)
Oil	0.24** (0.00)	0.21** (0.00)	0.14** (0.00)	0.13** (0.00)	0.12** (0.00)	0.13** (0.00)	0.13** (0.00)	0.14** (0.00)	0.11** (0.00)	0.07 (0.15)	0.10 (0.09)
Interest rate	−0.09* (0.01)	−0.11* (0.00)	−0.11* (0.00)	−0.09* (0.00)	−0.07* (0.00)	−0.07* (0.00)	−0.08* (0.00)	−0.09* (0.00)	−0.11* (0.00)	−0.11* (0.00)	−0.12** (0.00)
GPI	−0.04 (0.81)	−0.01 (0.37)	−0.01 (0.29)	−0.02** (0.01)	−0.02** (0.04)	−0.02** (0.04)	−0.02** (0.02)	−0.01** (0.02)	−0.02** (0.05)	−0.01* (0.03)	−0.03* (0.00)
COVID-19 deaths	0.02 (0.50)	0.01 (0.59)	0.01** (0.04)	0.03** (0.02)	−0.03** (0.00)	−0.03** (0.00)	−0.03** (0.01)	−0.02** (0.01)	−0.02** (0.01)	0.02** (0.02)	0.02** (0.01)
GPI * COVID-19 deaths	0.02* (0.77)	0.02* (0.59)	0.06* (0.02)	0.08* (0.02)	0.01* (0.00)	0.05* (0.01)	0.08* (0.00)	0.06* (0.02)	0.03* (0.001)	005* (0.0)	−0.04* (0.00)
VIX	0.05 (0.22)	0.05 (0.13)	0.06** (0.02)	0.07** (0.04)	0.11** (0.01)	0.17** (0.00)	0.20** (0.00)	0.23** (0.00)	0.24** (0.00)	0.23** (0.00)	0.27** (0.00)
Constant	1.32* (0.00)	1.47* (0.00)	1.47* (0.00)	1.44* (0.00)	1.34* (0.00)	1.12* (0.00)	1.01* (0.00)	0.98* (0.00)	0.98* (0.00)	1.10* (0.00)	1.02* (0.00)
Pseudo R^2	0.71	0.69	0.68	0.67	0.65	0.65	0.62	0.57	0.51	0.43	0.40
Dependent variable MSCI						Model III					
Variable	Q5	Q10	Q20	Q30	Q40	Q50	Q60	Q70	Q80	Q90	Q95
S&P stocks	0.44** (0.00)	0.35** (0.00)	0.39** (0.00)	0.38** (0.00)	0.40** (0.00)	0.44** (0.00)	0.48** (0.00)	0.48** (0.00)	0.49** (0.00)	0.43** (0.00)	0.45** (0.00)
Oil	0.10** (0.00)	0.22** (0.00)	0.16 (0.00)	0.17** (0.00)	0.12** (0.00)	0.10** (0.00)	0.09** (0.00)	0.09** (0.01)	0.11 (0.17)	0.09 (0.35)	0.11 (0.28)
Interest rate	0.07** (0.00)	0.06** (0.00)	0.06** (0.00)	0.06** (0.00)	0.06** (0.00)	0.07** (0.00)	0.08** (0.00)	0.09** (0.00)	0.09** (0.00)	0.07** (0.00)	0.07** (0.00)
GPI	−0.02** (0.01)	−0.01** (0.03)	−0.01** (0.03)	−0.01** (0.00)	−0.01** (0.00)	−0.02** (0.01)	−0.01** (0.01)	−0.02** (0.03)	−0.02 (0.16)	−0.05 (0.06)	−0.06 (0.11)
EV	−0.06** (0.00)	−0.04** (0.01)	−0.04** (0.01)	−0.05** (0.00)	−0.04** (0.04)	−0.06** (0.00)	0.03** (0.00)	0.03** (0.00)	0.03** (0.03)	0.08** (0.03)	0.11 (0.13)
GPI * EV	0.02 (0.06)	0.01 (0.06)	0.01 (0.19)	0.01** (0.03)	0.03** (0.04)	0.02** (0.00)	0.02** (0.03)	0.01** (0.00)	0.01** (0.02)	0.03** (0.00)	0.04 (0.14)
VIX	0.16** (0.00)	0.07** (0.00)	0.08** (0.00)	0.01** (0.00)	0.12** (0.00)	0.16** (0.00)	0.18** (0.00)	0.20** (0.00)	0.23** (0.00)	0.20** (0.01)	0.22** (0.02)
Constant	1.35* (0.00)	1.48* (0.00)	1.47* (0.00)	1.48* (0.00)	1.44* (0.00)	1.36* (0.00)	1.21* (0.00)	1.14* (0.00)	1.09* (0.00)	1.41* (0.00)	1.32* (0.00)
Pseudo R^2	0.66	0.69	0.69	0.67	0.67	0.66	0.62	0.58	0.51	0.44	0.40

Note(s): Figures in the parenthesis are p values. (*), (**) and (***) denote the level of significance of 1, 5 and 10%, respectively. QR denotes quantile regression moderating impact of the GPI is positive (Tables 2–4). Such findings confirm H3 of our study. These findings confirm the study by Chowdhury *et al.* (2021) and Chien *et al.* (2021). The results renew the scope of analysis of the geopolitics of sustainable and green energy transitioning during post-pandemic recovery.

4.2 Discussion

The outbreak of the global COVID-19 pandemic has adversely impacted the financial markets drastically, snowballing from the plunge in the real sector. Our study has investigated the impact of the COVID-19 pandemic on the stock market performance of three major clean energy markets, namely, RENIXX; WilderHill clean stocks and MSCI stocks. The results based on the quantile regression estimation have demonstrated the asymmetric impact on the RENIXX. The impact of the pandemic owing to the incidence of cases and death rates on the WilderHill clean stocks and MSCI stocks is positive. Our results, thus, exhibit the importance of investor attention toward clean energy firms. This study is a trailblazer in the extant seam of the empirical literature on the optimistic green recovery of the financial markets. Given this performance in the clean and green energy markets, there emerge more pronounced possibilities of green policy incentives in post-recovery periods. However, a lot depends on the underlying global structural changes and critical issues related to the demand for fossil fuel energy vis-à-vis platforms on climate welfare supporting greenhouse gas mitigations (Flamos *et al.*, 2011; Rezec and Scholtens, 2017; Hemrit and Benlagha, 2021).

Our findings have raised the crucial question of the relationship between sustainable energy and the geopolitics of energy transition under the precarious backdrop of the pandemic. This study found a positive moderating impact of the pandemics and GPI on the performance of clean energy stocks. The crucial question that is emerging from these findings is whether there will be a trend of transformation toward green sustainable energy use in future.

In sum, our study, confirming the earlier works in the literature (Wang and Su, 2020; Wang *et al.*, 2021a), lends support to the view that investment in the renewable energy sector could be a catalyst in generating demand for renewable energy use. The findings of this research on investors sentiment against the backdrop of the pandemic create new opportunities for the clean energy sector as part of the recovery strategy post-pandemic. Furthermore, it is expected as a part of expansionary monetary policy that the interest rates will remain low. With depressing global oil prices, there are key implications for the trajectory of renewable energy demand (Fernandes, 2020).

The discussion in the literature has amply explained that investments in the clean energy and renewables can generate positive externalities for the economy and the environment (Apergis and Payne, 2014; Ferrer *et al.*, 2018). Once the investment potential of the renewable energy is realized, it will turn into the prime energy source in the near future. The pandemic provided the right situation for the investments in the renewable energy, as evident from the empirical findings of this research. These findings confirm the works by Dincer (2020) and Bertrand *et al.* (2020). Over the past year, the installation of new renewables has been successful, and there is a greater prioritization toward clean energy investments (Ghabri *et al.*, 2021; Hemrit and Benlagha, 2021). In tune with the discussion in the literature, our findings amply describe the pandemic-induced investments in the renewable energy sector. Our findings verify the contentions, the importance of environmental aspects in financial investments like green investments and thereby the establishment and deployment of the renewable energy projects during the pandemic.

The most important finding of this exercise is that COVID-19 impacts the renewable energy stocks differently. The lockdown measures made the energy consumption unstable. On account of the downswings in the conventional energy sources, investors began to look into alternative avenues, by investing in the renewables. Differences in performance across the quantiles indeed offer the variations in the sentiments of the investors on consumption of the renewable energy. The negative impact of COVID-19 on the lower quantiles demonstrates that the investors lose the confidence during the bearish market conditions. These findings suggest that governments should announce relief packages to minimize the losses owing to the uncertainties. The central banks should instill the confidence by adjustment of monetary policies through lowering of the rate of interests.

5. Conclusions and policy implications

This paper has explored the impact of the recent COVID-19 pandemic on the stock performance of three major clean energy markets: RENIXX, WilderHill Index and MSCI Index. We explored the impact of incidence of cases due to the pandemic and death rates upon the stock performance. Our results show that for the RENIXX, the impact of both incidence of COVID-19 cases and death rates is asymmetric. However, the impact of COVID-19 cases and death rates on the WilderHill Index and MSCI Index is positive across all quantiles. The impact of the volatility index induced by the EV on the stock performance for the MSCI Index and WilderHill Index is asymmetric. The impact of the control variables confirms with the earlier findings in the literature. The moderating impact of the GPI on the stock performance of clean energy markets is significant and positive. This current empirical exercise makes a unique contribution to the theory pertaining to the investors' responsiveness and shift in decisions and behavior in the backdrop of bewildering and unparallel crisis.

This study has important policy implications. It is necessary to assess the long-lasting severity and uncertainty of the impact of the pandemic on the economy, based upon which policymakers should identify the short-term goals for prioritizing green energy use; specific attention should be put to the importance of spillover effects of the crisis upon the clean energy markets. This pandemic has given us an essential lesson owing to the disruptions. The governments of the major economies should propose draft regulations on renewable energy investments and protect economies from further instability. The consequences of the pandemic have taught us that based on the initial repercussions on the clean energy markets, the economic transformation toward clean energy use is imperative in the long run. Considering the overall impact of the geopolitics between COVID-19 and clean energy markets, there is a growing need to address the importance of green energy concerns. This is particularly important for ensuring energy availability at the household level across all socio-economic groups in such odd circumstances. Across the globe, the governments of the major nations can consider a proper allocation of resources in the form of financial incentives to boost investment in green and clean energy markets. Such exercise has the benefit of fulfilling the twin objective of rebooting the economy and moving to the trajectory of low-carbon emission targets.

5.1 Limitations of the study and directions of future research

Regarding the limitations of the present study and future research directions, we considered oil prices, interest rate and the Chicago Board Volatility Index as control; future research could explore the inclusion of some newer control variables to substantiate the results of the current study. Furthermore, there is the pressing need to explore spillover effects across energy markets with updated data, particularly considering the possibility of the second and third waves of COVID-19. Another potential extension of the present study would be exploring the importance of geopolitics and energy market spillover effects across the developed, developing and emerging economies.

References

Ahmad, W., Sadorsky, P. and Sharma, A. (2018), "Optimal hedge ratios for clean energy equities", *Economic Modelling*, Vol. 72, pp. 278-295.

Apergis, N. and Payne, J.E. (2014), "Renewable energy, output, CO2 emissions, and fossil fuel prices in Central America: evidence from a nonlinear panel smooth transition vector error correction model", *Energy Economics*, Vol. 42, pp. 226-232.

Azimli, A. (2020), "The impact of COVID-19 on the degree of dependence and structure of risk-return relationship: a quantile regression approach", *Finance Research Letters*, Vol. 36, p. 101648, doi: 10.1016/j.frl.2020.101648.

Baker, S.R., Bloom, N., Davis, S.J., Kost, K., Sammon, M. and Viratyosin, T. (2020). "The unprecedented stock market reaction to COVID-19", *The Review of Asset Pricing Studies*, Vol. 10 No.4, pp. 742-758.

Bertrand, M., Briscese, G., Grignani, M. and Nassar, S. (2020), *How are Americans coping with the COVID-19 crisis? 7 key findings from household survey*, Rustandy Center| Chicago Booth, Chicago.

Bodie, Z., Kane, A. and Marcus, A.J. (2010), *Essentials of Investments*, 8th ed., McGraw-Hill, New York.

Bondia, R., Ghosh, S. and Kanjilal, K. (2016), "International crude oil prices and the stock prices of clean energy and technology companies: evidence from non-linear cointegration tests with unknown structural breaks", *Energy*, Vol. 101, pp. 558-565.

Bouri, E., Demirer, R., Gupta, R. and Marfatia, H.A. (2019), "Geopolitical risks and movements in Islamic bond and equity markets: a note", *Defence and Peace Economics*, Vol. 30 No. 3, pp. 367-379.

Caldara, D. and Iacoviello, M. (2018), "Measuring geopolitical risk", FRB International Finance Discussion Paper No. 1222, FRB, available at: https://dx.doi.org/10.17016/IFDP.2018.1222 (accessed 22 July 2021).

Chien, F., Sadiq, M., Kamran, H.W., Nawaz, M.A., Hussain, M.S. and Raza, M. (2021), "Co-movement of energy prices and stock market return: environmental wavelet nexus of COVID-19 pandemic from the USA, Europe, and China", *Environmental Science and Pollution Research*, Vol. 28, pp. 32359-32373, doi: 10.1007/s11356-021-12938-2.

Chowdhury, M.A.F., Meo, M.S. and Aloui, C. (2021), "How world uncertainties and global pandemics destabilized food, energy and stock markets? Fresh evidence from quantile-on-quantile regressions", *International Review of Financial Analysis*, Vol. 76, p. 101759, doi: 10.1016/j.irfa.2021.101759.

Dincer, I. (2020), "Covid-19 coronavirus: closing carbon age, but opening hydrogen age", *International Journal of Energy Research*, Vol. 44 No. 8, p. 6093.

Dutta, A., Bouri, E. and Roubaud, D. (2019), "Nonlinear relationships amongst the implied volatilities of crude oil and precious metals", *Resources Policy*, Vol. 61, pp. 473-478.

Fernandes, N. (2020). "Economic effects of coronavirus outbreak (COVID-19) on the world economy", available at: SSRN 3557504.

Ferrer, R., Shahzad, S.J.H., López, R. and Jareño, F. (2018), "Time and frequency dynamics of connectedness between renewable energy stocks and crude oil prices", *Energy Economics*, Vol. 76, pp. 1-20.

Flamos, A., Georgallis, P.G., Doukas, H. and Psarras, J. (2011), "Using biomass to achieve European Union energy targets—a review of biomass status, potential, and supporting policies", *International Journal of Green Energy*, Vol. 8 No. 4, pp. 411-428.

Ghabri, Y., Ayadi, A. and Guesmi, K. (2021), "Fossil energy and clean energy stock markets under COVID-19 pandemic", *Applied Economics"*, Vol. 53 No. 43, pp. 4962-4974, doi: 10.1080/00036846.2021.1912284.

Gillingham, K.T., Knittel, C.R., Li, J., Ovaere, M. and Reguant, M. (2020), "The short-run and long-run effects of covid-19 on energy and the environment", *Joule*, Vol. 4 No. 7, pp. 1337-1341.

Hemrit, W. and Benlagha, N. (2021), "Does renewable energy index respond to the pandemic uncertainty?", *Renewable Energy*, Vol. 177, pp. 336-347, doi: 10.1016/j.renene.2021.05.130.

Hoang, A.T., Nižetić, S., Olcer, A.I., Ong, H.C., Chen, W.H., Chong, C.T., Thomas, S., Bandh, S. and Nguyen, X.P. (2021), "Impacts of COVID-19 pandemic on the global energy system and the shift progress to renewable energy: opportunities, challenges, and policy implications", *Energy Policy*, Vol. 154, p. 112322, doi: 10.1016/j.enpol.2021.112322.

Kahneman, D. and Tversky, A. (2013), "Prospect theory: an analysis of decision under risk", in MacLean, L.C. and Ziemba, W.T. (Eds), *Handbook of the Fundamentals of Financial Decision Making: Part I*, World Scientific Publishing, pp. 99-127.

Khan, M.I., Yasmeen, T., Shakoor, A., Khan, N.B. and Muhammad, R. (2017), "Oil plunge: causes and impacts on renewable energy", *Renewable and Sustainable Energy Reviews*, Vol. 68, pp. 609-622.

Kim, S.T. and Orlova, S. (2021), "Is Bitcoin Immune to the COVID-19 pandemic?", *Applied Finance Letters*, Vol. 10, pp. 48-57.

Koenker, R. and Bassett, G. Jr. (1978), "Regression quantiles", *Econometrica: Journal of the Econometric Society*, Vol. 46 No. 1, pp. 33-50.

Kouton, J. (2019), "The asymmetric linkage between energy use and economic growth in selected African countries: evidence from a nonlinear panel autoregressive distributed lag model", *Energy Economics*, Vol. 83, pp. 475-490.

Kumar, S. (2017), "On the nonlinear relation between crude oil and gold", *Resources Policy*, Vol. 51, pp. 219-224.

Liu, T. and Hamori, S. (2020), "Spillovers to renewable energy stocks in the US and Europe: are they different?", *Energies*, Vol. 13 No. 12, p. 3162, doi: 10.3390/en13123162.

Mishra, P.K. and Mishra, S.K. (2020), "Corona pandemic and stock Market Behaviour: empirical insights from selected Asian countries", *Millennial Asia*, Vol. 11 No. 3, pp. 341-365.

Moya-Martínez, P., Ferrer-Lapena, R. and Escribano-Sotos, F. (2015), "Interest rate changes and stock returns in Spain: a wavelet analysis", *BRQ Business Research Quarterly*, Vol. 18 No. 2, pp. 95-110.

Rezec, M. and Scholtens, B. (2017), "Financing energy transformation: the role of renewable energy equity indices", *International Journal of Green Energy*, Vol. 14 No. 4, pp. 368-378.

Sadorsky, P. (1999), "Oil price shocks and stock market activity", *Energy Economics*, Vol. 21 No. 5, pp. 449-469.

Wan, D., Xue, R., Linnenluecke, M., Tian, J. and Shan, Y. (2021), "The impact of investor attention during COVID-19 on investment in clean energy versus fossil fuel firms", *Finance Research Letters*, Vol. 43, p. 101955, doi: 10.1016/j.frl.2021.101955.

Wang, Q. and Su, M. (2020), "Drivers of decoupling economic growth from carbon emission–an empirical analysis of 192 countries using decoupling model and decomposition method", *Environmental Impact Assessment Review*, Vol. 81, p. 106356, doi: 10.1016/j.eiar.2019.106356.

Wang, Q.J., Chen, D. and Chang, C.P. (2021a), "The impact of COVID-19 on stock prices of solar enterprises: a comprehensive evidence based on the government response and confirmed cases", *International Journal of Green Energy*, Vol. 18 No. 5, pp. 443-456.

Wang, K., Wang, Y. and Chang, C.P. (2021b), "The impacts of COVID-19 pandemic on air pollution from energy consumption: diverse evidence from China", *International Journal of Green Energy*, Vol. 19 No. 1, pp. 84-94.

Xie, Y., Kang, S.B. and Zhao, J. (2021), "Are stablecoins safe havens for traditional cryptocurrencies? An empirical study during the COVID-19 pandemic", *Applied Finance Letters*, Vol. 10, pp. 2-9.

Zaremba, A., Kizys, R., Aharon, D.Y. and Demir, E. (2020), "Infected markets: novel coronavirus, government interventions, and stock return volatility around the globe", *Finance Research Letters*, Vol. 35, p. 101597, doi: 10.1016/j.frl.2020.101597.

Further reading

Allen, D.E., Gerrans, P., Powell, R. and Singh, A.K. (2009), "Quantile regression: its application in investment analysis", *Jassa*, Vol. 4, pp. 7-12.

Ang, A., Chen, J. and Xing, Y. (2006), "Downside risk", *The Review of Financial Studies*, Vol. 19 No. 4, pp. 1191-1239.

Baur, D.G. (2013), "The structure and degree of dependence: a quantile regression approach", *Journal of Banking and Finance*, Vol. 37 No. 3, pp. 786-798.

Lee, B.S. and Li, L. (2016), "The idiosyncratic risk-return relation: a quantile regression approach based on the prospect theory", *Journal of Behavioral Finance*, Vol. 17 No. 2, pp. 124-143.

Maiti, M. (2019), "OLS versus quantile regression in extreme distributions", *Contaduría Y Administration*, Vol. 64 No. 2, pp. 1-10.

Markowitz, H. (1952), "Portfolio selection", *The Journal of Finance*, Vol. 7 No. 1, pp. 77-91.

Corresponding author
Sudeshna Ghosh can be contacted at: sudeshna.ghoshsent@outlook.com