Co-movement of energy prices and stock market return: environmental wavelet nexus of COVID-19 pandemic from the USA, Europe, and China

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Abstract

This work aims to study the time-frequency relationship between the recent COVID-19 pandemic and instabilities in oil price and the stock market, geopolitical risks, and uncertainty in the economic policy in the USA, Europe, and China. The coherence wavelet method and the wavelet-based Granger causality tests are applied to the data (31st December 2019 to 1st August 2020) based on daily COVID-19 observations, oil prices, US-EPU, the US geopolitical risk index, and the US stock price index. The short- and long-term COVID-19 consequences are depicted differently and may initially be viewed as an economic crisis. The results illustrate the reduced industrial productivity, which intensifies with the increase in the pandemic's severeness (i.e., a 10.57% decrease in the productivity index with a 1% increase in the pandemic severeness). Similarly, indices for oil demand, stock market, GDP growth, and electricity demand decrease significantly with an increase in the pandemic severeness index (i.e., a 1% increase in the pandemic severeness results in a 0.9%, 0.67%, 1.12%, and 0.65% decrease, respectively). However, the oil market shows low co-movement with the stock exchange, exchange rate, and gold markets. Therefore, investors and the government are recommended to invest in the oil market to generate revenue during the sanctions period.

Keywords Wavelet coherence · COVID-19 · Stock market · Oil prices · Global pandemic

Introduction

Human suffering and loss of life are the primary outcomes of any pandemic. WHO (26th September 2020) (World Health Organization 2020) has already recorded 32,429,965 confirmed cases and 985,823 deaths from COVID-19. Such pandemics also cause several multi-dimensional setbacks to the economy and environment. Although the specifics of how much an economy gets affected by COVID-19 are not clear, 30% of the worldwide residents are under lockdown due to the

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severe infection rate. An ~80% of the global labor force faces closed workplaces and an overall anticipated slump of 0.7%, adding to some of the economic impacts recorded as of now (the worst since the Great Depression) (Sun et al. 2020a, b, c; Samadi et al. 2020). Carbon dioxide (CO_2) emissions consist of several forms among GHGs that are harmful environmental consequences of human activities (Ikram et al. 2019a, b; Sun et al. 2019). For instance, Ren et al. (2014) discovered that excessive trade surplus coupled with enormous FDI inflows are the main motives for the rapidly rising CO_2 emissions in China. Researchers use an estimate for the cost of deaths to measure the financial consequences of pandemics with CO_2 emission. For instance, global influenza (the 1918 epidemic) caused a loss recorded at 500–600 billion USD$/year, measuring up to 0.6% of the global GDP. This effect is higher for low-middle income countries (1.6%) as compared with high-income nations (0.3%) (Mzoughi et al. 2020). According to a joint report by World Health Organization (WHO) and the World Bank, the impact of the present epidemic, however, can cause a loss of 2.2 to 4.8% in the global GDP (3 trillion USD) (Personal et al. 2016). An (IMF 2020) report points out that the pandemic will severely affect the poor population due to their inability to access enough health care and financial assistance (Tiep et al. 2021).

The sudden drop in oil prices and the major markets' stock prices state the obvious loss from the coronavirus outbreak (Alemzero et al. 2020a, b; Sun et al. 2020a; Gharib et al. 2020). A fall in the stock prices states how the stock prices for the USA, UK, and Italy fell by 32%, 27.9%, and 39.3%, respectively. The stock prices for emerging markets face a decline; notably, Brazil, Russia, and China declined by 40.5%, 24.2%, and 10.1%, respectively. In contrast, a loss of $9 trillion is observed since the outbreak (Sudha et al. 2020). According to some analysts (Jelilov et al. 2020; Haarmeyer 2020), the panic caused out of fear among the investors is the reason for this fall in prices. An expected combination of two factors, combined with the trail of non-OPEC supply growth is expected. This combination is meant to create a balance in the oil price market during the second half of 2020. With an increase in the pandemic, a 30% sudden loss occurred in oil price, which is the highest fall after the Gulf War of 1991 (Prabheesh et al. 2020; Iqbal et al. 2020).

The stock market is significantly affected by the news around oil prices and the COVID-19 outbreak (Fig. 1). Although oil markets are expected to recuperate which is uncertain to estimate the short- and long-term impacts of the coronavirus outbreak (Yousaf et al. 2020; Tehreem et al. 2020; Wasif Rasheed and Anser 2017; Xu et al. 2020). This uncertainty poses a significant concern for the US policymakers (Corbet et al. 2020, 2021). Esso and Keho (2016) used cointegration bounds testing and Granger causality to investigate the long-term and causal association between energy consumption, CO_2 emissions, (Asif et al. 2020; Sarker et al. 2020; Iram et al. 2020; Tehreem et al. 2020), and economic growth. The observational findings are mixed across economies in order to explore the causal relationships regarding energy consumption, carbon dioxide (CO_2) emissions, and economic growth in (Toda and Yamamoto 1995) Granger causality system. In earlier study, Chuku et al. (2011) used a similar approach and found that trade has no influencing factor CO_2 emissions in Nigeria. The concerns under discussion serve as the foundation for this study, making it the first attempt at analyzing the connection and the competition between different players, such as the EU, USA, and China, based on the factors, including the stock market interplay and COVID-19, and oil price. This study uses the wavelet method, focusing on the continuous wavelet transform
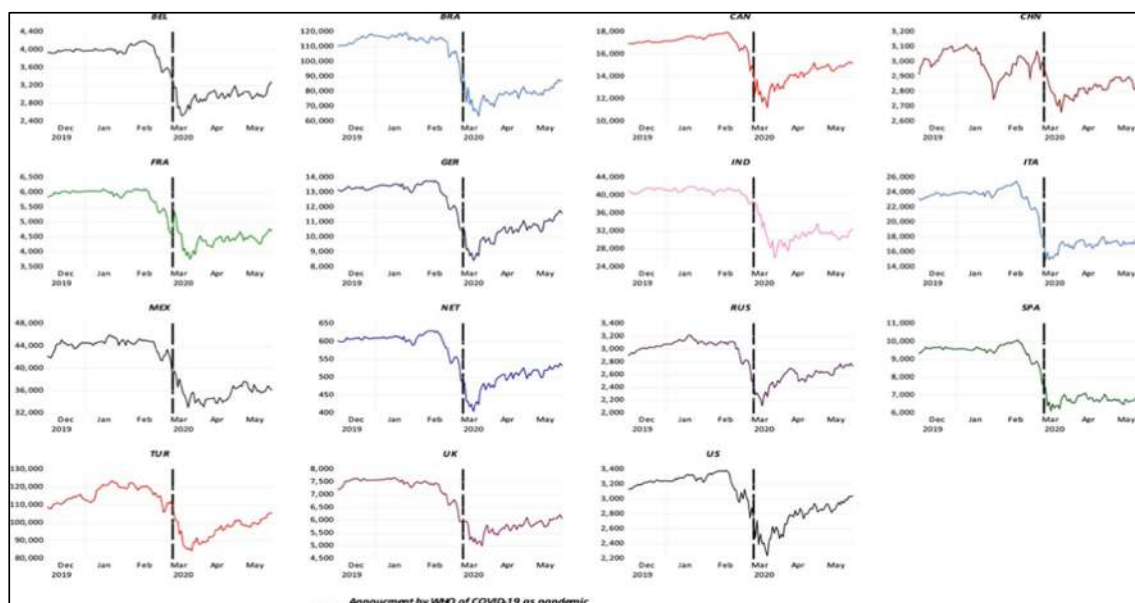

Fig. 1 Global stocks (daily) December 2019–May 2020

(CWT), wavelet coherence (WC), wavelet spectrum, and the wavelet-based causality tests, implemented on recent data from the USA. A hypothesis is formed based on the given data, explaining the relationship between the news around the COVID-19 pandemic, oil price volatility, and US stock market. The fundamental factor characterizes the time series on its movement. Secondly, the wavelet methods are applied with a nonlinear relationship. Researchers will need data over more extended periods to measure the present and the future time-frequency which is essential to achieve a greater arithmetical implication after the applied tests. Therefore, this study cannot utilize traditional econometric techniques. The current study uses the wavelet method due to no effect of sample size on its results.

This study can prove crucial for policymakers and investors to identify movement in co-moving markets and their direction across various periods. It will also help define if this co-movement will affect a third market. This research can also help study fluctuations caused by a specific market on other markets and the measure to stabilize the affected market.

Data and methodology

Wavelet approach

The wavelet model is a potent estimation tool with a single chance to assess co-movements between economic series across the time-frequency dimension through signal processing. It provides significant insights regarding the possible interdependence for different scales. The wavelet analysis extracts information along time and the frequency dimension through time-series spectral bands as a function of time, making it a more effective tool than the other standard methods (Anser et al. 2020e; Khalid Anser et al. 2020). The single occasion truncated in a single frequency range, and the coherent structures across varying scales are differentiated through this method. It employs both locally stationary and non-stationary data, making it a popular economics method due to its flexibility. For a given period, the small "wave packet" in wavelet is seen to go through a rise and fall, whereas the wavelet functions are determined by factors, such as ψ in L^2 (R). It was documented to be effective with stationary time series (Bilal et al. 2020). According to the indicators of the World Bank (2018), a CO_2 emission intensity in Nigeria was 0.59 in 1990 rose to 0.71 in 2014. Also, the performance of trade has witnessed imbalance growth over the years in Nigeria. Most recently, trade experienced an all-time high (53% of GDP in 2011) but dropped to 20% in 2016 due to economic uncertainties. This tells us that industrialization in Nigeria has not been fully utilized because the country is a net importer of goods and services.

It is not suitable to stay restricted to stationary time series when considering complicated. Traditional spectral tools are more likely to miss frequency components that may appear, disappear, and reappear over time. It is possible to overcome the stationarity through wavelet filters as they offer an inherent platform. Events, local in time, are easily captured by the wavelet transform due to its ability to attach itself to capture features across a wide range of occurrences. Therefore, the wavelet transform is the perfect tool to study the non-stationary time series. Factors necessary for the application of Fourier transform include the presence of cyclic time series and the ability of occurrences to not progress with time (for details, see (Lopez-Tiro et al. 2020)). The frame in the wavelet transform keeps varying from low to high and high to low frequency. The analysis of a definite wavelet ψ (.) against the time sequence $x(t) \in L^2(R)$ provides wavelet transforms $Wx(m, n)$ shown as:

$$W_x(m, n) = \int_{-\infty}^{\infty} x(t) \frac{1}{\sqrt{n}} \overline{\psi\left(\frac{t-m}{N}\right)} dt. \tag{1}$$

The ability of continuous wavelet transforms to decompose and accordingly recreate as time series $x(t) \in L^2(R)$ is one of its essential characteristics, given as:

$$x(t) = \frac{1}{C_\psi} \int_0^\infty \left[\int_{-\infty}^\infty W_x(m, n)\psi_{m,n}(t)du\right] \frac{dn}{N^2}, N > 0 \tag{2}$$

Furthermore, the power of the observed time sequence is preserved by the continuous wavelet transform,

$$\|x\|^2 = \frac{1}{C_\psi} \int_0^\infty \left[\int_{-\infty}^\infty |W_x(m, n)|^2 dm\right] \frac{dn}{N^2} \tag{3}$$

The definition of wavelet coherence is stated in this study as quantifying the size and defined framework.

Cross-wavelet transform

The two sequences for cross wavelet transform $x(t)$ and $y(t)$ are explained as $WXY = WXWY*$, where WX and WY represent the two transforms for wavelets x and y, respectively, whereas the composite conjugation is signified by the asterisk sign. With the given time period, the mixed debate (WXY) is considered the original analogous stage between xn and yn (Malhotra and Chintanpalli 2020) as,

$$D\left(\frac{\left|W_n^X(s)W_n^{Y*}(S)\right|}{\sigma X \sigma Y} < p\right) = \frac{U\vartheta(p)}{\vartheta}\sqrt{P_k^X P_{k,}^y} \tag{4}$$

The assurance level connected with the likelihood p for a likelihood density purpose is $U\vartheta(p)$, described by the square root of the product of two $\chi2$ distributions.

Wavelet coherence

Wavelet coherence is the bivariate structure introduced to analyze the association between two-time series. For an adequate description of wavelet coherence, the cross wavelet transform and cross-wavelet power should be defined first. This two-time sequence $x(t)$ and $y(t)$ can explain the cross wavelet transform as:

$$W_{xy}(m,n) = W_x(m,n)W_y^*(m,n) \quad (5)$$

where the two continuous wavelet transforms of $x(t)$ and $y(t)$ are given as $Wx(m,n)$ and $Wy(m,n)$, the location index as m, the measure as n, and a composite conjugate as the sign *. The cross-wavelet transform given as $|Wx(m,n)|$ can easily calculate the cross-wavelet power. A time-frequency gap can be observed by wavelet coherence for a continuously changing time series, which does not necessarily show a massive mutual power (Kisi and Cimen 2011). The equation for the adjusted wavelet coherence coefficient can be seen as follows:

$$R^2(m,n) = \frac{\left|N\left(N^{-1}W_{xy}(m,n)\right)\right|^2}{N\left(N^{-1}|W_x(m,n)|^2\right)N\left(N^{-1}|W_y(m,n)|^2\right)} \quad (6)$$

S represents the smoothing mechanism, and $0 \le R^2(m,n) \le 1$ represents the range of squared wavelet coherence coefficient. Values closer to one imply a more robust correlation, whereas values closer to zero imply a weaker correlation. In this study, the hypothetical allocation for the wavelet coherence cannot be identified, hence using Monte Carlo methods. The method given by Torrence and Compo (1998) and Grinsted et al. (2004) is used in the study for the examination process. Edge situations on data are challenging to manage when using the wavelet approach; Grinsted et al. (2004) defines shaft of control as regions where errors impacted by breaks and gaps in the wavelet transform can be ignored, and the boundary impacts become crucial.

Wavelet coefficients smaller than a threshold are eliminated by hard thresholding. The hard shrinkage function is given by Eq. (3):

$$x_{ht} = \begin{cases} 0 & if\, |x| \le \quad \lambda \\ x & if\, |x| > \quad \lambda \end{cases} \quad (7)$$

Mid thresholding can be adopted as a flexible method, as it provides the mid shrinkage function is given by Eq. (4):

$$x_{ht} = \begin{cases} 0 & if\, |x| \le \quad \lambda \\ x - \dfrac{\lambda 2}{x} & if\, |x| > \quad \lambda \end{cases} \quad (8)$$

Same like Donoho and Johnstone (1995) in this study, the soft-thresholding method generates better results than mid and hard thresholds in a continuous shrinkage function. The soft shrinkage function is represented as Eq. (5):

$$x_{ht} = \begin{cases} 0 & if\, |x| \le \quad \lambda \\ |x| - s\log\left(1 + \dfrac{|x|}{S}\right) & if\, |x| > \quad \lambda \end{cases} \quad (9)$$

Inspired by Granger and Ramanathan (1984) and Geweke (1992), Breitung and Candelon (2006) used a method for causality analysis in the frequency domain. This method is different from the concept of alternative partial directed coherence (PDC). The Granger causality (GC) frequency domain is explained in detail by the given method, as it classifies the two series based on spectral interdependence. According to Breitung and Candelon (2006), the test presents the relationship reformulation between x and y in the VAR(p) equation as follows:

$$x = a_1 x_{t-1} + \ldots + a_p x_{t-p} + \beta_1 y_{t-1} + \ldots + \beta_p y_{t-p} + \beta_{1t} \quad (10)$$

The null hypothesis was tested by Geweke (1992) for the null linear restriction, given as:

$$H_0 : My{\rightarrow}x(\omega) = 0.$$

Data and variable selection

Calculated by the Dow Jones 30 index, the data used by this study consists of daily COVID-19 observations, oil prices (WTI), US-EPU (news-based index), the USA-geopolitical risk index (GPR), and the US stock price index (SPI). Centers for Disease Control and Prevention (CDC)'s website is used to gather the data for COVID-19. Similarly, DataStream is the source of data on oil and US stock market, whereas the website of economic policy uncertainty is used for the information on EPU. Caldara and Iacoviello (2018) and Antonakakis et al. (2017) database is used to collect the US-GPR index. Fifty observations for the data collected from 21st January 2020 to 30th March 2020.

Results and discussion

The uncertainties about the economy and higher concerns for future economic costs as COVID-19 unfolds in the future are the factors making our results valuable. The economic costs will only increase with the spread of COVID-19. Loss of employee productivity, loss of consumer demand, an adverse impact on tourism and other industries, and an impact on foreign direct investment are some of the fundamental factors considered to measure the challenges posed by potential pandemics, both in terms of costs to the health systems and costs of social distancing, before COVID-19. Results show the

continuous wavelet transforms (CWT) plots for individual variables. Each variable's movements in the time-scales and frequency bands can be analyzed through CWT. In response to Saudi Arabia's least expected price discount announcement and the meltdown in crude oil markets, the risk to the US stock market is evident. CO_2 refers to emission intensity (kg per kg of oil equivalent energy use), I is the gross domestic income, and TI is the trade integration measured by the division of total export and total import of goods and services percentage of GDP. FDI refers to the foreign direct investment net inflows; GDP points to the gross domestic product in growth rate (K) measured by the gross fixed capital formation. This paper used the ARDL bounds testing to cointegration techniques where yearly data from 1980 to 2018 were used. The use of ARDL was called for because we assume linearity to permit us to examine the long-run relationship and possible impact of the explanatory variables on CO_2 emissions that ought to remain the same or uniform.

The EPU index shows a moderately different pattern. The EPU index volatility is high in the starting period due to the increase in the novel infectious disease and China's turbulent sanitary conditions. The EPU for the USA shows the highest value at the end of the sample (around 400 by the end of March 2020), which suggests the unmatched value of EPU in the USA. According to Fig. 2, the CWT plot aligns with the time path of the EPU index. It is easy to spot the two islands with high volatilities for the 1–8 and up to 16-day-frequency bands for the time path of oil price starting in February. The CWT for the visual inspection of the US COVID-19 count shows small islands of high volatility from the beginning of the sample period. The reading coincides with the first wave of deaths in the USA as a result of COVID-19. During the US-GPR inspection, the CWT plot is observed to be a mixture free fall of oil prices that are suggested to be responsible for the unexpected rise in an uncertainty. As the US-GPR drops from 559 points to less than 100 points at the beginning of the month, a huge red color island equivalent to considerable instability shocks is identified through the end of February 2020.

Figure 3 shows oil and stock wavelet spectrum. In the scenario of market flooding, the countries of Middle-East can therefore assume payment for sacrificing short-run revenues, while the opportunity cost of these two strategies is reliant on the Middle-East countries' revenue objective function (Anser et al. 2020a, c, f, g, h).

Figure 4 shows the oil and stock prices trend at different time horizon. The arrows are pointed upward and left, which implies the US stock market's leading role in the US-EPU. However, the US market's sudden decrease points to the significant uncertainty about its economic policy. Frequency bands with upward and right arrows, whereas the oil prices continuously fall down due to the decrease in transport and lower expectation of the output growth. The price of oil has a detrimental effect on the socio-economic development of the importing countries as buyers and suppliers of goods and services both struggle.

The vulnerability of the oil i.e., higher costs, contributes to higher vulnerability values. Diversified reserves of oil could result in less risk for disruption. A nation's reliance on oil imports and the risk of oil supply (Anser et al. 2020d) are prone to be more risky in terms of oil supply shortage. A similar amount of oil imported from different oil suppliers is assumed to be facing the very same risk, focusing on four kinds of diversification indexes and the risk of oil supply.

Table 1 shows the oil and stock return. The risk factor with the US dollar is calculated as the amount of the first log discrepancy measured in the volatility of the regular US dollar index. The risk factor of dependence is integrated inside the oil sources to assess risk. Random effect estimator is preferred over the Hausman test due to its insignificantly statistical chi-square. The results show the positive effect on the development of the stock exchange sector of foreign direct investment (FDI). In the long-term tests, their importance is 5%, while in the short-term outcomes, their importance is 10%. The WPI has an important positive influence on the development of stock exchange market. The values of both long and short runs are important at 10%. The real prices of oil (ROP) have a significant positive influence on the production of the stock exchange industry. The significant values are at 1% both long- and short-terms. Nevertheless, the money in circulation has a little effect on the development of the stock exchange industry.

According to Black Monday and Black Tuesday, natural gas companies have the highest stocks, unexpectedly earning between +17% and +11% daily. It could be due to crude petroleum producers' ability to draw natural gas as a by-product of the oil extraction process. Due to the oil price decrease in March 2020, crude producers limited natural gas production from the reduced oil output. Six shows an oil-EPU connectedness for different time-scales and frequencies. The recent oil price seriously affects the US economic policy.

Figure 5 shows the COVID-19 index data. US-GPR levels are significantly affected by the massive spread of COVID-19. The wavelet plot is enlightening for dependence between the oil and US-GPR. A considerable measure of dependence can be seen at the initial and end periods of the sample. The 4–8-day frequency is covered at the beginning of the sample. The upward left-aligned arrows demonstrate the association of stock market and oil prices. Results present the upward right-aligned arrows, up to 16 days of investment horizons, demonstrating GPR as a fundamental variable.

In particular, we considered the drought response framework of crude oil supply companies, in which the residential sector of the urban crude oil supply industry adjusts the reduction of crude oil supply in a given year. Small-scale and short-duration crude oil supply interruptions show the large amount

Fig. 2 Oil and stock wavelet coherence
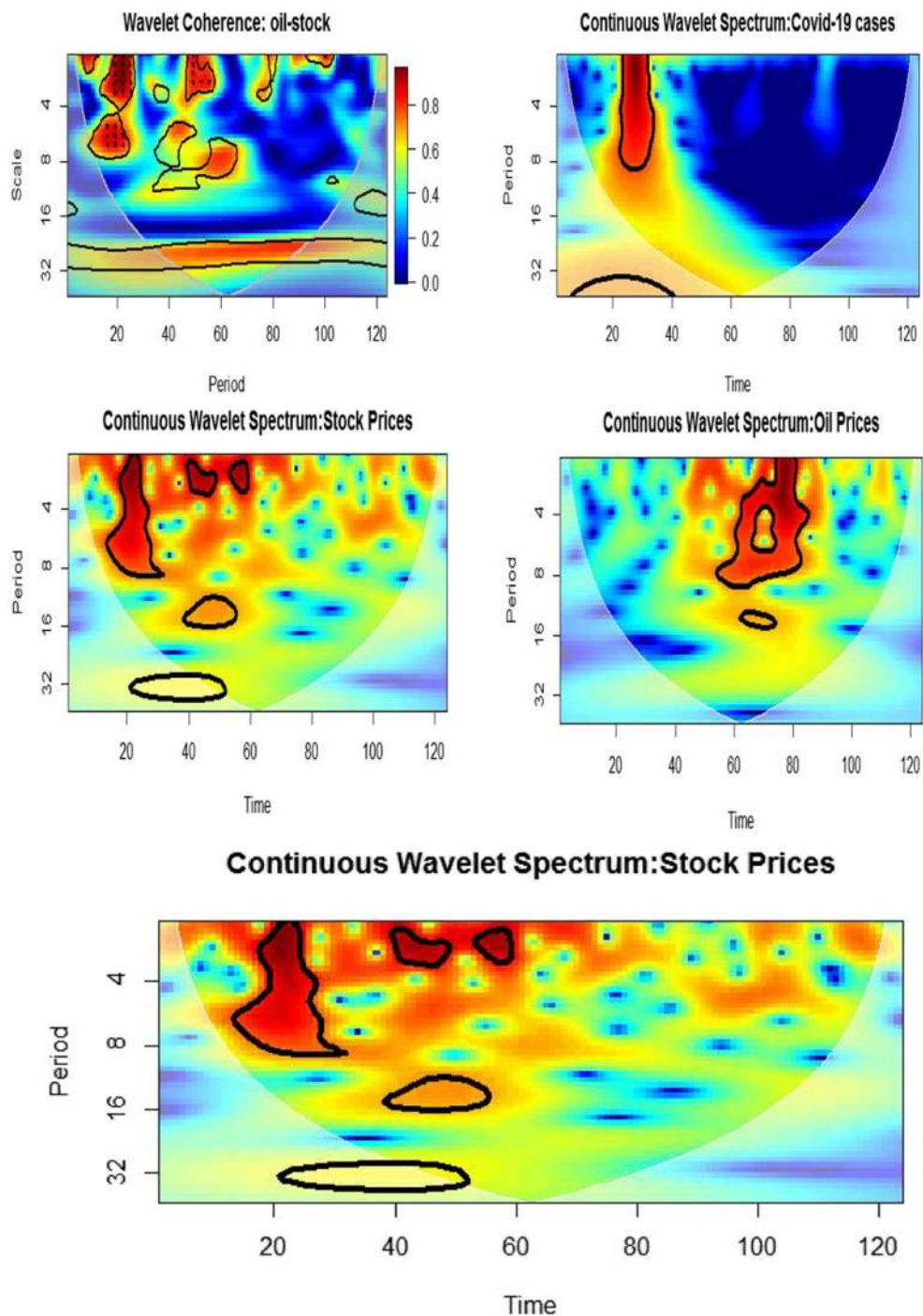
of capital investment required for 1 year and shortened the long-term interruption to short-term. Spatial distribution effects of these three sources of heterogeneity occured in the data. We will also discuss equity considerations based on the IBP schedule. Finally, we estimated and discussed the inefficiency of the distribution of proportional distribution and effective distribution among various utility companies during the regional supply interruption. The environmental impacts of COVID-19 should be addressed to assess the overall effects

of the pandemic's socio-economic impacts. Coronavirus causes more than 2.2 billion tons of carbon emission reduction, which makes it the most significant fall recorded in the last century. However, this paper suggests 1.8–2.0 billion tons reduction in carbon emission. Nevertheless, it is still too early to determine whether this pandemic positively or negatively impacts the climate in the long-run.

Table 2 shows a 0.002 increase in the average co-movement of oil prices and exchange rates, which was

Fig. 3 Oil and stock continous wavelet spectrum
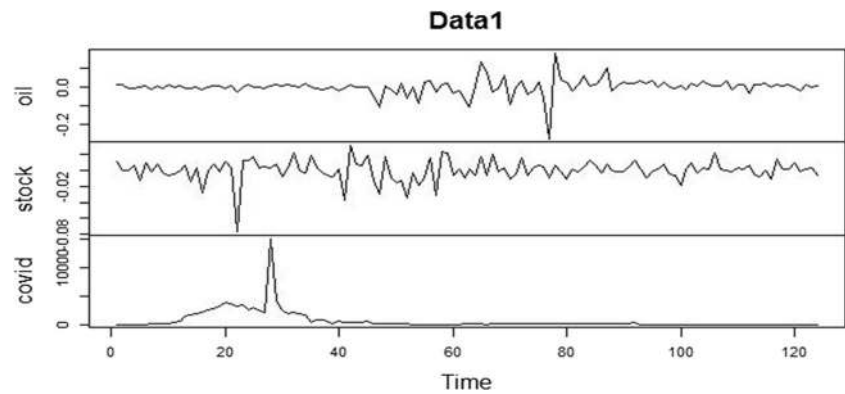
0.18 at the beginning of the period under study (September 2014). However, significant correlation or changes between the two variables are not visible with the sanctions' start (May 2018). At the beginning of the sanctions, the co-movement reached −0.17 as it decreased over time. These two variables were considerably affected by the sanctions. The highest value of average co-movement in the pair of variables, gold prices–exchange rates (0.62), was observed at the beginning of the considered period. With time, a continuous decrease was observed until it reached zero for the start of the sanctions. Although the two variables did not observe any significant co-movement, the average co-movement of gold prices and exchange rates observed significant and positive changes during the sanction period. The co-movement of the exchange rates–stock prices pair was recorded at 0.06 at the beginning of the study period and did not vary significantly over time. At the beginning of the sanctions, a 0.2 increase in the average co-movement was observed, decreasing over time. Companies of Middle East are administrated by in the favor of the in the scenario of market flooding; the countries of Middle East can therefore assume payment for sacrificing short-run revenues while the opportunity cost of these two strategies depends on the objective revenue role of the Middle-East countries.

The consideration of extreme cases two polar objective functions wherever they insert all weight autonomous from any political effect at the oil market. They select and design their strategy on the base of reduced collected oil revenues. They also adopt the option of the scenario of market flooding solitary for discount rates lesser than 7%.

The size, activity, and efficiency of financial intermediaries and the stock market's activity and efficiency are directly related to COVID-19, oil, stock exchange, and gold. During the COVID-19 outbreak, the logarithm of trade openness is included in the control variable set. The standard errors indicate 1%, 5%, and 10% significance are included in parentheses, which are ***, **, and *, respectively. The inverted U-shaped relationship between financial structural activity and economic growth is shown in the first column of Table 3. Statistically positive and negative values for the linear and quadratic terms of financial structure

activity can precisely be found here. The marginal effect of financial structural activity seems to turn negative when it reaches up to 168%, as shown in the regression point estimate (Mohsin et al. 2020). COVID-19 is widely concerned with social actors, policymakers, and society as a whole. The literature indicates that the COVID-19 outbreak has wide influences on oil prices and stock market performance. Studies highlighted through the wavelet analysis technique that the COVID-19 outbreak is significantly impacting stock market volatility. More so, COVID-19 is causing negative national economic growth and rising uncertainty in the markets and negatively affecting the oil prices. These results are proved by using a lead-lag relationship and linear relationships. The associations between COVID-19, oil prices, and stock market return variables vary across time-scales and investment horizons, where both cyclical and anti-cyclical patterns of connectedness have been identified. The outcome of the relationship between carbon (CO_2) emissions and fixed capital is consistent with that reported in Mohsin et al. (2018b, 2019, 2020). The authors found that increased fixed capital has reduced carbon (CO_2) emissions and enhanced environmental efficiency.

Robustness analysis

As mentioned in earlier studies, the US market's considerable sensitivity to oil volatility shocks stated their alignment with the results given above. The effect of D1 and D2 does not cause the US-GPR risk levels over all the selected frequency bands. This result may occur as US investors consider the COVID-19 eruption primarily as a financial catastrophe instead of a reverse geopolitical event. Considering the two exogenous shocks as being independent, the oil price volatility over the remaining frequency domains is unaffected by the effects of COVID-19.

It is not feasible to produce and refine 10% of the global oil from the fall in the oil price to the pre-twenty-first-century mark Mohsin et al. (2018a, 2019). Therefore, it is up to the oil-producing countries to control the energy market, which helps their consumers from facing worse economic circumstances.
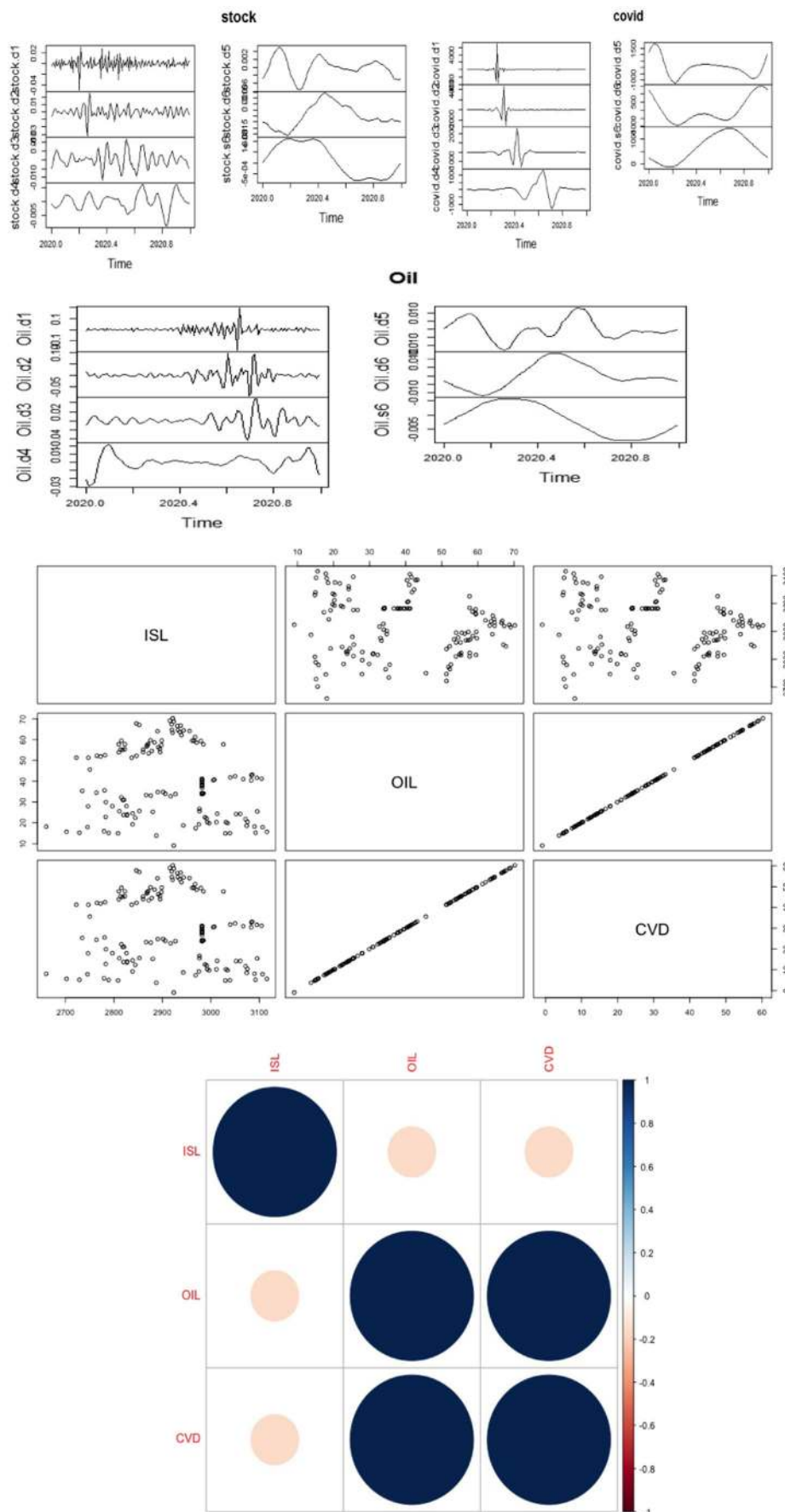
Fig. 4 Oil and stock shocks and trend behaviors

Table 1 Oil and stock return

S&P 500	NSDAQ	DOW	DAX	CRIA	Shanghai	Cyprus SE	CROBEX	Oil prices	Oil return
0.01	0.01	0.00	0.00	0.00	0.01	0.00	0.00	34.15$	0.01
0.02	0.00	−0.01	0.01	−0.04	0.01	0.00	0.01	33.98$	−0.01
0.01	0.01	0.02	0.01	0.00	−0.01	0.00	0.00	32.73$	0.02
−0.02	0.00	0.02	−0.01	0.00	0.00	0.00	0.00	33.95$	−0.06
0.01	0.00	0.00	0.01	0.00	0.00	0.00	−0.01	33.80$	−0.01
−0.03	−0.01	0.00	−0.03	−0.01	0.00	0.01	−0.01	34.78$	0.02
0.00	0.02	0.02	0.02	0.00	0.01	−0.01	0.00	34.76$	0.01
0.01	−0.01	−0.02	−0.01	−0.05	0.00	0.00	0.00	33.06$	0.03
−0.01	0.02	0.04	0.00	0.00	0.00	0.01	0.00	33.30$	−0.01
0.00	0.01	0.00	−0.01	0.00	0.01	0.00	0.00	30.95$	0.03
0.00	0.01	0.02	0.01	0.00	−0.01	0.00	0.00	29.87$	0.02
0.02	−0.02	−0.02	0.03	0.07	0.00	0.00	0.00	27.89$	0.02
0.01	−0.02	−0.02	0.00	0.03	−0.01	0.00	0.00	26.67$	−0.09
0.01	0.01	0.00	0.00	0.00	0.00	0.01	0.00	25.53$	0.02
−0.06	0.02	0.02	−0.04	0.00	0.01	−0.01	0.00	24.23$	0.02
−0.01	0.01	0.01	−0.01	−0.01	0.00	0.01	0.00	24.20$	−0.03
−0.01	0.01	−0.01	−0.02	−0.04	0.00	0.00	0.00	25.46$	0.06
0.01	0.01	0.01	0.00	−0.16	0.00	0.01	0.00	20.40$	0.01
0.03	0.01	0.00	0.03	−0.01	0.00	0.00	0.00	18.49$	0.01
0.00	−0.03	−0.03	0.00	−0.02	0.00	0.00	0.00	18.11$	0.03
0.01	0.00	−0.01	0.04	0.00	0.02	0.01	0.01	17.86$	0.07

Table 4 shows the sensitivity analysis based on Granger causality. The causality is strongly influencing the oil price for all the selected frequencies for EPU. It is suggested that the uncertainty in the US economic conditions is the main cause of an increase of the GPR levels. Recent studies have indicated novel changes in sustainable products like cleaning and sanitizing the workplace, implementing social distance, minimizing travel, and reducing transportation. However, novel changes about the supply chains, social innovations, and technology have been observed due to the coronavirus outbreak (Sarkis et al. 2020). The production and supply system are interrupted from the outbreak of the COVID-19, and strategies
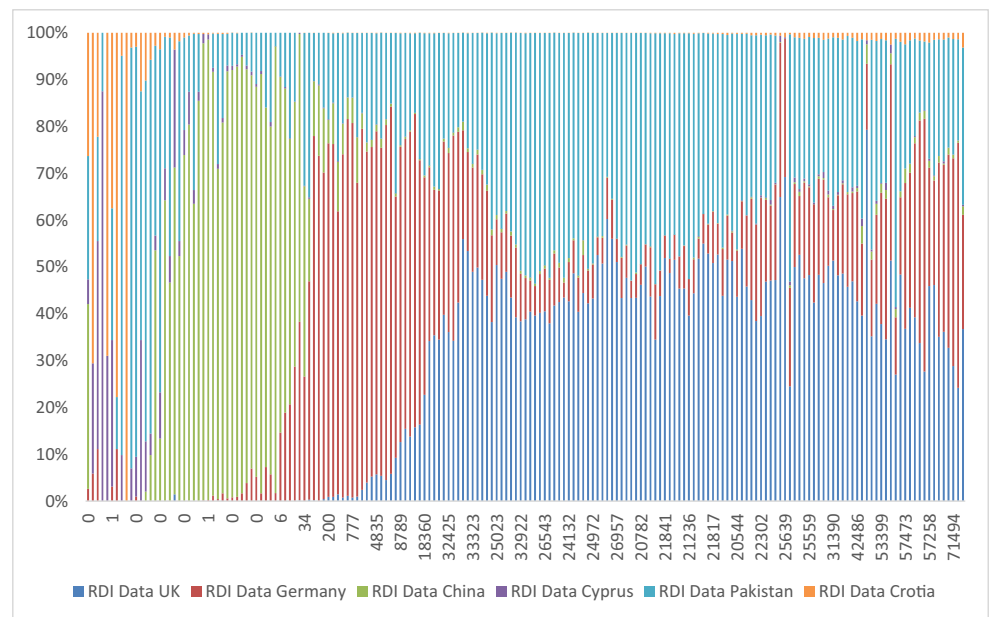
Fig. 5 COVID-19 index data

Table 2 Econometric estimation

Dependent variable→Coefficient	β_0	β_1	β_2	β_3	β_4	β_5	F-static
Exchange rate and stock price	0.06 (0.00)	0.004 (0.10)	0.19 (0.00)	−0.006 (0.04)	0.20 (0.80)	−0.003 (0.92)	13.45 (0.00)
Gold price and exchange rate	0.59 (0.00)	−0.005 (0.00)	−0.041 (0.33)	0.004 (0.02)	0.51 (0.74)	−0.007 (0.76)	17.53 (0.00)
Gold price and stock price	0.15 (0.00)	0.0008 (0.53)	0.21 (0.01)	−0.002 (0.16)	1.02 (0.29)	−0.009 (0.3)	12.43 (0.00)
Oil price and gold price	0.14 (0.00)	−0.002 (0.00)	−0.12 (0.00)	0.007 (0.00)	0.30 (0.70)	0.008 (0.50)	29.32 (0.00)
Oil price and stock price	0.07(0.00)	0.003 (0.00)	0.11(0.21)	−0.002 (0.09)	0.37 (0.69)	−0.008 (0.66)	6.76 (0.00)
Oil price and exchange rate	0.21 (0.00)	0.002 (0.00)	−0.01 (0.17)	−0.001 (0.80)	−0.29 (0.73)	0.005 (0.34)	18.34 (0.00)

and policies are set to design new patterns and deal with the demand of consumers for production. It is vivid that raw products and raw materials were supplied from China and Asian countries worldwide. Still, the pandemic situation gave a break to the transportation, and supply was shortened. Thus, priorities were given to the demand for basic and mandatory products and services. Therefore, policy strategies are set to improve the system's resilience and sustainability (Khalid Anser et al. 2020; Mohsin et al. 2021; Yang et al. 2021). The economic and market fluctuations have contributed to the sustainability transition and enabled us to remain proactive to respond to the challenges. Besides the consumption of mass products, integration of social, economic, environmental, and institutional opportunities offer opportunities. Government restrictions and volunteer social distancing created room for the investigation filled with this study (Anser et al. 2020b; He et al. 2020).

Environmental consideration regarding COVID-19

The ongoing situation of the COVID-19 pandemic illustrated remarkable effects on the global economy where green finance enabled significant measures to sustain the economy's environment. Various proactive approaches used in global to establish dominant alliances to support the economy, but macroeconomic factors also stated significant influence among them. COVID-19 established all possible effects over the economic growth with green finance dominance, which helped global to pose a sustainable environment for economic growth. The serious contradiction also eminently discussed in the environment of economic growth and green finance's resilience established positive measures though. Plenty of challenges effectively prevailed in global economies, but the effectiveness of green finance inserted possible influences with covering measures to safe economic growth.

Table 3 Effects of financial structure on economic growth

	(1)	(2)	(3)	(4)	(5)	(6)
	Boldrin and Levine (2002)			Cuadro-Sáez and García-Herrero (2007)		
COVID-19	0.188			0.454		
	(0.253)			(0.599)		
Oil		0.729***			1.711***	
		(0.221)			(0.512)	
Stock			0.421**			1.06**
			(0.137)			(0.473)
Lag of dependent variable	0.199**	0.152***	0.053	0.162**	0.176***	0.067
	(0.061)	(0.053)	(0.051)	(0.053)	(0.061)	(0.049)
Gold	−0.782***	−0.822***	−1.013***	−0.921***	−0.888***	−1.041***
	(0.197)	(0.194)	(0.305)	(0.222)	(0.259)	(0.323)
Trade openness	1.748***	1.865***	0.712*	1.399***	1.582***	0.702*
	(0.496)	(0.403)	(0.426)	(0.486)	(0.375)	(0.466)
Constant	4.433	4.490	6.605**	4.622	5.522*	7.717**
	(2.775)	(2.645)	(3.173)	(3.062)	(2.568)	(3.202)
AR(2) p-value	0.782	0.885	0.642	0.920	0.966	0.192
Hansen p-value	0.442	0.546	0.997	0.534	0.783	0.995

This table reports the estimation results of model (1). The dependent variable is real GDP

* Shows 10% significance level, ** shows 5% significance level, *** Shows 1% significance level

Table 4 Sensitivity analysis wavelet-based Granger causality

Frequency domains	Dependent variables	Independent variables			
		Stock	COVID-19	Gold	Oil
D1	Stock		0.813	17.382***	
	COVID-19	7.613*	–	19.583***	1.584
	Gold	61.844***	1.548	–	22.491***
	Oil	30.324***	2.984	09.524**	–
D2	Stock		0.813	17.382***	
	COVID-19	7.984*	–	18.783***	1.876
	Gold	62.564***	1.763	–	21.723***
	Oil	31.785***	2.862	10.621**	–
D3	Stock		0.813	17.382***	
	COVID-19	6.632*	–	17.743***	1.654
	Gold	61.634***	1.895	–	20.8643***
	Oil	32.785***	2.657	10.787**	–
D4	Stock		0.986	18.657***	
	COVID-19	7.002*	–	18.863***	1.786
	Gold	62.434***	1.764	–	21.864***
	Oil	32.785***	2.657	10.787**	–
D5	Stock		0.813	17.382***	
	COVID-19	6.632*	–	17.743***	1.654
	Gold	61.634***	1.895	–	20.8643***
	Oil	32.785***	2.657	10.787**	–
D6	Stock		0.986	18.657***	
	COVID-19	7.002*	–	18.863***	1.786
	Gold	62.434***	1.764	–	21.864***
	Oil	32.785***	2.657	10.787**	–
Original	Stock		0.986	18.657***	
	COVID-19	7.002*	–	18.863***	1.786
	Gold	62.434***	1.764	–	21.864***
	Oil	32.785***	2.657	10.787**	–

* Shows 10% significance level, ** shows 5% significance level, *** Shows 1% significance level

The element of environmental concern is included in the other areas in the maintenance of the status of inclusive economic development, and it proves its significance with the statistics from the population of the region. The energy sector plays a backbone role in the economy of any country. Over time, this sector is getting more and more important. Green credit initiatives are important to make the economy stable and well-established. Eco-friendly biofuels and recyclable material usage are essential for the growth of the economy. Green credit investment options are beneficial for Pakistan's prosperity. Green securities are safe investment options for the well-being of green economic growth and development. The use of environmentally friendly materials in business firms for manufacturing purposes is imperative for the community's well-being. Developed countries like China have implemented safe financing approaches for the well-being of their

economy. The companies have proper strategies to support the health insurance and other health-related implications. Environmental sustainability options are essential to support prosperity and economic growth.

Discussion

A global-scale decrease in environmental pollution was observed due to a significant decrease in energy demand during the lockdown period. 2020 is likely to face the biggest fall in global energy demand which is expected to be around 5%. As compared with the same period in 2019, the end of April is said to experience a 17% decrease in worldwide emissions (Kannan et al. 2020), and global lockdown is considered the fundamental drivers for measuring the extent of emission

reduction effect of COVID-19, suggesting a potential reduction of 7%. Index-only investments during 2019–2020 can directly be compared with the downside for portfolios containing ethereum and tether. The only evidence for a reduction in downside risk of ethereum is due to CSI 300. A significant increase is found with an MVaR of 11.47% at a 1% confidence level for FTSE 100, but when combined with 10% ethereum, it increases by 28.9% with the remaining 90% allocated to the FTSE 100. Over this period, tether provides safe-haven characteristics. A reduction in the downside risk is observed with Tether's allocation for each of the equity indices.

However, the safe-haven properties of Tether cannot be confirmed through this data. If a firm freezes between Tethers, a 10% decrease in downside risk should occur from a 10% allocation, which is equivalent to 10% of the unallocated portfolio in the presence of the US dollar. Considering a range of different allocation weights, we test this concept and the proportional reduction in downside risk across all the assets. However, this is novel evidence, confirming empirically that they have impacted the stock returns themselves, once changes in conditional volatility are considered. Several events and activities are disrupted globally due to the pandemic COVID-19 and have dragged all the transformations occurring in the production of the goods and their supply. This has designed new actions and courses to go through the process of stock market business. Resultantly, transition in sustainability has become mandatory (Mohsin et al. 2020). COVID-19 signals for the change in new behavior for the suitable actions for the business managers and policymakers concerned with the sustainable production and supply and the transition in the prospects of sustainability (Sun et al. 2020b).

Conclusion and policy implication

This work examined the time-frequency relationship between the recent COVID-19 pandemic and instabilities in oil price and the stock market, geopolitical risks, and uncertainty in the economic policy in the USA, Europe, and China. The coherence wavelet method and the wavelet-based Granger causality tests are applied to the data (from 31st December 2019 to 1st August 2020) based on daily COVID-19 observations, oil prices, US-EPU, the US-geopolitical risk index, and the US stock price index. The findings show a dramatic fall in oil and stock prices with an increase in the severity of COVID-19, which is found to be significantly strong post-5th April 2020. The March 2020 COVID-19 stock crash was one of the largest stock market crashes in history, where the market had a 26% fall in four days. The US GDP of the first quarter of 2020 was down 4.8%, while the unemployment rate was over 20%.

Analysis from the wavelet-based approach helps overcome practical challenges (such as stationarity and non-linearity) by analyzing time-frequency lead-lag interactions. Results from

the segmented regression analysis illustrate the significance of the re-imposition of sanctions between gold prices and exchange rates. Consequently, short-, medium-, or long-term investments in either gold or foreign exchange are risks for investors during the COVID-19 pandemic. This finding is essential for policy-makers and government officials, who can control the foreign exchange market to stabilize the gold market in crisis times. The oil market shows low co-movement with the stock exchange, exchange rate, and gold markets. Therefore, investors and the government are recommended to invest in the oil market to generate revenue during the sanctions period. This study contributes to the vast pool of literature on COVID-19 and its financial implications, particularly focusing on Bitcoin as a potential investment in this pandemic situation.

These results about the introduction of environmental aspects into the financial policies like a green investment and securities, and thereby the movement in the establishment and development of the renewable energy enterprises in an economy where the pandemic COVID-19 prevails.

Policy implication

Green investment initiatives are the credit options that have future implications for the development and prosperity of the economy of a country. In developing countries, insurance-based options are scarce, but efforts are in progress for the economic sector's well-being. Business communities throughout the world have focused on the development of green insurance-based options. The companies are providing green investment platforms that support the overall green credit loans. Companies all over the world have a transparent set of social and economic development initiatives that supplement the overall green economy and green investments. These initiatives support the eco-friendly approaches and show the extent of social responsibility in the industries. The new and innovative production units generate no harmful effluents and waste materials. These plants are not only cost-effective but also supportive of the growth and development of economic growth initiatives. Biomass and agricultural wastes are abundant in developing countries. Developing economies can use all these wastes for the generation of bio-friendly fuels. These fuels can easily produce new and innovative products. These products can easily support the infrastructure of the country. Industrial units that have adopted eco-friendly ways of production have more production rate than the traditional industrial units. The need is to enhance the number of such eco-friendly and economically sound industrial units.

Hussain: writing—review and editing and software. Muhammad Raza: editing, reviewing.

Data availability The data that support the findings of this study are openly available on request.

Declarations

Ethical approval and consent to participate N/A

Consent for publication We do not have any individual person's data in any form.

Competing interest The authors declare that they have no conflict of interest.

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