



Since January 2020 Elsevier has created a COVID-19 resource centre with free information in English and Mandarin on the novel coronavirus COVID-19. The COVID-19 resource centre is hosted on Elsevier Connect, the company's public news and information website.

Elsevier hereby grants permission to make all its COVID-19-related research that is available on the COVID-19 resource centre - including this research content - immediately available in PubMed Central and other publicly funded repositories, such as the WHO COVID database with rights for unrestricted research re-use and analyses in any form or by any means with acknowledgement of the original source. These permissions are granted for free by Elsevier for as long as the COVID-19 resource centre remains active.



Global economic performance and natural resources commodity prices volatility: Evidence from pre and post COVID-19 era

Li Sun^{a,b}, Yang Wang^{b,*}

^a School of Economics, Jilin University, Changchun, 130012, China

^b School of Economics, The Institute of American Studies, Jilin University, Changchun, 130012, China

ARTICLE INFO

Keywords:

Natural resource commodity price volatility
Global economic performance
Breitung-candelon spectral granger causality
Covid-19

ABSTRACT

The emergence of Covid-19 has created a global panic that affects global economic performance and causes natural resources commodity price volatility. In this regard, the current research study investigated the nexus of natural resource commodity price volatility and global economic performance from January 01, 2019, to July 01, 2021. Using the wavelet power spectrum and wavelet coherence approaches, the empirical findings reveal that only the natural resource commodity prices are vulnerable. However, no vulnerability has been observed for the global economic performance. Additionally, the wavelet coherence reveals that there is no long-run or the short run causal association between these two variables. Moreover, the Breitung-Candelon spectral Granger causality test confirms no causal relationship between natural resource commodity price volatility and global economic performance. Based on the empirical findings, this study provides some relevant policy implications.

1. Introduction

Since the beginning of the 21st century, the world has faced many challenges in the earlier decades, such as volatility in natural resource oil price, global financial crises, and the recent Covid-19 pandemic outbreak that discourages economic performance all around the world. Besides, crude oil in the global market has faced a significant downturn during the last two decades, specifically in the 2007–08 financial crises and Covid-19 pandemic crisis (Guan et al., 2021). In recent times, the world has been facing two major shocks: (i) the outbreak of Covid-19 pandemic and (ii) the drop in the global natural resource commodity oil price (Sharif et al., 2020). The intersection of such two issues will almost certainly trigger a long-term economic depression, plunging the leading (US) economy and other economies of the world into another recession. The Covid-19 epidemic keeps spreading rapidly across the globe, producing record stock market volatility and economic policy uncertainty, with current stock volatility levels rivaling or exceeding those seen in October 1987, December 2008, and the 1929 stock market crash (Sharif et al., 2020). Besides the stock market volatility, recent studies argued that not only Covid-19 significantly promote natural resources commodity (crude oil) price volatility but also other factors such as Russia and Saudi Arabia trade war and negative oil price news (Zhang, 2021; Albulescu, 2020; Bourghelle et al., 2021). Besides, these

studies argued that an increase in the Covid-19 new cases and death ratio significantly enhances volatility between 8% and 22%. Moreover, Gil-Alana and Monge (2020), in their recent study, empirically explored that this natural resource commodity oil price shock in the Covid-19 pandemic is persistent and long lasting. (see Table 1)

Concerning volatility or Uncertainty, many studies argued that natural resources, specifically oil prices, adversely affect the country's economic growth projected by the rising inflation and unemployment by degrading the financial assets, specifically in the oil-importing economies (Sauter and Awerbuch, 2003). Still, the results are not consistent, as all the studies indicate diverse outcomes. The earlier study of Hooker (1996) unveils that there is no causal association between the natural resource commodity oil prices and economic performance by analyzing the data after 1980. In contrast, a number of studies, including Katoka and Dostal (2021), Hayat and Tahir (2021), Guan et al. (2021), Lardic and Mignon (2006, 2008), Brown and Yücel (2002), among others, that provide evidence for the asymmetric and non-linear association between the natural resource commodity price and economic performance. An increase in the natural resource commodity price, particularly, may well have a negative impact on economic activities. Still, a drop in the price of natural resource commodities does not always imply greater output levels. One might also argue that if an oil price decreases, it increases Uncertainty about price fluctuations; some of the increased production

* Corresponding author.

E-mail addresses: drilisun@outlook.com (L. Sun), dryangwang01@outlook.com (Y. Wang).

Table-1
Descriptive table.

	CROP	GLEP
Mean	51.51903	-0.803106
Median	54.07000	-2.057911
Maximum	75.93000	8.012987
Minimum	18.84000	-4.043798
Std. Dev.	13.01945	3.405818

would be countered by lower output levels as a result of increased Uncertainty. Therefore, rather than the oil price's level, the oil price's volatility (or Uncertainty) may be connected to the collective level of output. In this concern, [Bashar et al. \(2013\)](#) provide evidence that the natural resource commodity price does not influence the aggregate output level. However, the aftershocks of Uncertainty or volatility of natural resources commodity prices create panic and majorly contribute to the aggregate output level.

After World War II, oil became the major energy resource, particularly for transportation and manufacturing, and is vital in industrialized, developing, and emerging economies ([Su et al., 2020](#)). Crude oil has the largest market share in the commodities sector, accounting for around 40% of global energy consumption. Oil price volatility is a source of anxiety for economies, particularly those that are oil-dependent. The Uncertainty has negative and disruptive macroeconomic effects that, if not addressed, may become a hurdle to sustainable economic growth in the future ([Shakoor et al., 2020](#); [Su et al., 2021](#); [Ebrahim et al., 2014](#)). Petroleum crises such as the Arab oil embargo (1970), the Iran-Iraq conflict (1980), the first Gulf war (1990), the great recession/global economic crisis (2008), and the current Covid-19 pandemic (2020) enhance the instability in oil prices, which have a major impact in economic growth of the countries. Although supply and demand drive the long-term oil price pattern, oil-related events and speculating activity can enhance oil price volatility and create market uncertainty. As a result, business cycles and macroeconomic structures are greatly associated with natural resources price volatility ([Guan et al., 2021](#); [Sharma et al., 2021](#)). However, after the emergence of the Covid-19 pandemic, most of the economies across the globe have taken precautionary measures in response to the contagious pandemic ([Doğan et al., 2020](#); [Pandey et al., 2021](#)). This resulted in the global lockdown, which in turn offset economic and production activities ([Shahzad et al., 2021](#); [Sarwar et al., 2021](#)). It is believed that the fall in economic activities and transport, which is accounted for two-thirds of the oil demand, has seriously affected the oil demand ([Algamdi et al., 2021](#)). This reduction in the transport, production and economic activities significantly reduces the natural resource commodity demand in the global market, which decreases the prices of that commodity across in the global natural resource commodity market.

Since Covid-19 pandemic is a contagious disease and a source of symmetric risk, there is a need for further research on the economic effects of the Covid-19 pandemic at the global level. In this concern, the current study aims to analyze the volatile behavior of global economic performance and natural resource commodity prices throughout the selected time period. The specific method adopted by this study would identify the volatility of each variable across time. Another objective of this study is to empirically investigate the causal link between the global economic performance and natural resource commodity price volatility in pre and post pandemic periods. However, to achieve the former objective, this study used two approaches, the wavelet coherence, which identifies both the short and long-run causal association between the variables and the frequency domain causality (further details of the said approaches are provided in Section-3). This study utilized the recent data set for global data covering the period from January 01, 2019, to July 01, 2021. The considered dataset covered the critical economic crisis period of Covid-19 when oil prices dropped to the lowest, where oil traded at \$-37.63 per barrel. Whereas, prior to the oil price drop, the

natural resources market was moving rapidly towards stabilization. Therefore, this oil price drop makes it more volatile and fluctuating than usual.

In addition to the prior, this study employed the wavelet approach to analyze vulnerabilities and/or volatilities in the natural resource commodity prices, global economic performance, and their causal association. Prior to this study, the same approach is utilized by [Sharif et al. \(2020\)](#) to investigate the US economic policy uncertainty, oil prices and stock market in the Covid-19 pandemic, [Arain et al. \(2020\)](#) to analyze dynamic relationship between foreign direct investment, renewable energy, economic growth and carbon emission in China, [Adebayo and Akinsola \(2021\)](#) to examine the causal linkage between economic growth, energy consumption and CO₂ emissions in Thailand. These recent studies have adopted the mentioned methodology for vulnerabilities identification and causal association between the variables. After employing the said methodology, this study's results highlight significant long-run and short-run vulnerabilities in the natural resource prices. At the same time, no significant vulnerabilities have been identified in the global economic performance and the causal linkage between them (natural resources price volatility and global economic performance).

This study contributes to the existing literature in three ways. Firstly, this is one of the pioneering studies empirically investigating global economic performance and natural resource commodity prices volatility. Even though many studies contributed to the literature regarding oil prices and economic growth nexus. Still, a gap is present in economic performance and natural resources volatility, where this study attempts to fill this gap. Secondly, this study adopts both the pre and post Covid19 pandemic periods for empirical analysis. Although the literature displays many studies that have been done either in the pre-Covid-19 pandemic era or the post-Covid-19 pandemic era, no study considers both periods of pandemic. Therefore, this study is novel in contributing to the literature analyzing both the mentioned periods concerning volatility in natural resources and economic performance via time-frequency analysis. Lastly, the current used the most recent dataset for empirical investigation, which could better display the current global economic performance and natural resource commodity price scenarios from a global perspective.

The rest of the paper is organized as follow: Section-2 presents review of the relevant literature, that covers both the pre and post Covid-19 pandemic periods; Section-3 provides detailed methodology for both the wavelet approach and the frequency domain causality; Section-4 presents the estimated results and their discussion; finally, Section-5 provides conclusion and the policy implications.

2. Review of literature

Concerning the natural resource commodity price volatility and economic performance, many scholars and researchers have efforts to provide an extensive literature in both the pre and post pandemic periods. Based on the two pandemic periods, literature in the current study have been distributed into two groups: (i) natural resource commodity prices volatility and economic performance in the pre-pandemic period, and (ii) natural resources commodity prices in the post pandemic periods. Additionally, most of the studies targeted the crude oil prices as the natural resource commodity due to most traded natural resource that also covers 33% of the global energy demand ([Van Eyden et al., 2019](#)). Regarding the pre-Covid-19 pandemic period, many scholars, including [Katoka and Dostal \(2021\)](#), [Hayat and Tahir \(2021\)](#), [Guan et al. \(2021\)](#), [Mukhtarov et al. \(2020\)](#), [Atil et al. \(2020\)](#), [Rosnawintang et al. \(2021\)](#) among others, have empirically investigated the influence of natural resource(s) on economic and financial growth of various countries. While regarding the post-Covid-19 pandemic period scholars such as [Kartal \(2020\)](#), [Albulescu \(2020\)](#), [Prabheesh et al. \(2020\)](#), [Sharif et al. \(2020\)](#), [Gil-Alana and Monge \(2020\)](#), among others, empirically examined the influence of Covid-19 on both the economy and oil prices in

different countries and regions, which are specifically discussed below.

However, prior to the literature regarding natural resources and economic performance nexus, studies have extensively provided literature covering natural resource volatility in the post-Covid-19 pandemic era. In this regard, Zhang (2021) used the autoregressive heteroskedasticity model in China's case and revealed that Covid-19 pandemic positively influences oil stock volatility. Albulescu (2020) utilized the autoregressive distributed lags (ARDL) model and validates the earlier study that an increase in the new cases of Covid-19 negatively and significantly affects oil prices in the long-run US. In consistent with these findings, Gil-Alana and Monge (2020) conclude that Covid-19 plays a positive role in oil market inefficiency. Also, the study found that the oil price series is mean reverting, while the shock will have a long-lasting effect. Bourghelle et al. (2021) argued that the trade war between Russia and Saudi Arabia in the Covid-19 period leads to an uncertain situation, which encouraged supply shock in oil market. However, the shock and Uncertainty lead to higher volatility in the natural resource oil price. Besides, Narayan (2020) and Devpura and Narayan (2020) explored that Covid-19 active cases and Covid-19 death ratio and negative oil price news also increase volatility in the oil prices between 8% and 22%. Although these studies have mentioned volatility in the oil prices, they ignored most indicators, i.e., economic growth and economic performance in the Covid-19 pandemic.

Concerning wavelet approach, studies are available that consider the said approach to obtain both the short-run and long-run estimates and the causal association for appropriate policy making. In this regard, the recent study of Sharif et al. (2020) analyzed daily data via employing the wavelet approach and concludes that the US economic policy uncertainty and oil market is greatly sensitive to and influenced by the pandemic outbreak. Concerning macroeconomic variables leading variables and oil price dynamics, Hathroubi and Aloui (2020) utilized the partial and multiple wavelet coherence and unveils that non-oil GDP, trade balance, public expenditures, and oil prices showed volatility between 1970 and 2016 period. Besides, the study found a negative connection between non-oil balance and oil prices and a positive correlation between government expenditure and fluctuations in oil prices, revealing pro-cyclical fiscal policy.

2.1. Literature review on the natural resource commodity price and economic performance in the pre-covid-19 pandemic

One of Katoka and Dostal (2021) investigated economic performance, natural resources, and international commodity prices in 45 Sub-Saharan African economies covering the 1990–2019 period. The study used random coefficient model and concluded that natural resources contribute to economic growth. Also, the results found that natural resource countries specialized in commodity exports performs better than the other economies. In contrast, Rahim et al. (2021) found the presence of resource curse in the next-11 countries. However, the natural resources in the present of human capital development positively affect economic performance. The study of Hayat and Tahir (2021) investigated resource-rich economies including Oman, Saudi Arabia, and UAE throughout 1970–2016 and employed autoregressive distributed lag (ARDL) model. The results obtained reveal that natural resources positively and significantly affect economic growth only in UAE and Saudi Arabia. However, the volatility of the natural resource negatively influences economic growth in the three countries. Concerning energy consumption, oil price and economic performance, Shahbaz et al. (2017) and Sarwar et al. (2017) provide evidence about the existence of bidirectional causal association between oil price and economic growth. Also, these studies argued that oil price significantly affect economic growth in OECD countries. On the other hand, Waheed et al. (2020) argued that capital formation could be an efficient tool to boost renewable energy and tourism investment for sustainable economic growth in Saudi Arabia.

Guan et al. (2021) examined natural resource price volatility and

economic growth while employing the pooled mean group (PMG) and ARDL approaches concerning natural resource dependent countries. The results unveil that the natural resources price volatility could be detrimental to economic growth in the long-run. However, economies behave differently in the short run. In the pre-Covid-19 pandemic period, Mukhtarov et al. (2020) examined the influence of oil prices on economic growth and other macroeconomic variables between January 2005 and January 2019 in Azerbaijan. The study found that cointegration exists between these variables using the Johansen cointegration and vector error correction model (VECM) approaches. Further, the study confirms that oil prices positively and significantly affect economic growth. Prior to Covid-19 pandemic, Bashar et al. (2013) investigated the oil price uncertainty and the macroeconomy of Canada while using the structural VAR model. The results asserted that the oil price shock does not exert an effect on the aggregate output level. However, the Uncertainty in the oil prices significantly contributes to the variations in the output levels. Also, the study illustrates that the oil price uncertainty reduces the durable and non-durable manufacturing in the sub-sectors. A similar insignificant causal association between the oil prices and macroeconomy has been found by the earlier study of Hooker (1996), which investigated the data after 1980.

In case of Pakistan, Atil et al. (2020) the finance growth linkage while analyzing the role of oil prices throughout the 1972–2017 period. The study employed the long-run co-variability approach and concluded that although natural resources promote financial development. However, the oil prices negatively affect financial development in the region. The study of Cevik et al. (2020) investigated oil prices, stock market, and volatility spillover in Turkey. The data covers the period from 1990 to 2017 and employed EGARCH analyzing technique. The results explore that the oil prices significantly affect the stock market of Turkey. However, the study does not provide the spillover effect of oil prices, whereas the crude oil spillover effect is found only in 1993 and 2008–2009. Using the panel ARDL approach, Rosnawintang et al. (2021) investigated the crude oil prices volatility impact on economic growth in ASEAN-5 economies over the 1995–2018 period. The study reveals that the crude oil price volatility negatively affects economic growth in the short run only. In contrast, Millia et al. (2020) used ARDL approach in the case of Indonesia throughout 1995–2018 and discovered that the crude oil prices volatility does not significantly affect the tourist arrival in the region. Although, the tourism industry has a significant contribution to the economy. Still, the influence of crude oil prices volatility is not significant in the tourists' arrival.

2.2. Literature review on the natural resource commodity price and economic performance in the post-covid-19 pandemic

One of the recent studies of Kartal (2020) investigated the Covid-19 pandemic impact on the Turkey's oil prices. The study uses daily data from July 25, 2019, to October 30, 2020 and employed a multivariate adaptive regression. The results asserted that the volatility index affects oil prices. Also, the Covid-19 pandemic affect the local currency oil prices in the country. Albulescu (2020) investigated daily data from January 21 to March 13, 2020 and employed the ARDL model concerning oil prices and economic policy uncertainty in the US. The study results report that the Covid-19 deaths and cases increase do not affect economic policy uncertainty in the US. However, the oil prices negatively affect economic policy uncertainty in the Covid-19. For the case of top ten oil exporting economies, Prabheesh et al. (2020) investigated the time-varying dependence between stock markets and oil prices. The study analyzed daily data while employing the DCC-GARCH approach and exhibited the time varying dependence of oil prices and the stock market. Besides, this reduction leads to the fall of the stock market due to lower future's profitability, that further decline economic activities.

Additionally, Sharif et al. (2020) studied oil prices and economic Uncertainty along with the other macroeconomic factors in the case of the US. Using the wavelet based approach, the study reveals that the

association between the variables varies across time. However, the Covid-19 pandemic has a greater influence on the economic Uncertainty of the US economy. Moreover, the authors argued that oil is the leading market in the US that displays both lower and higher frequencies across the observations. In continuation, [Gil-Alana and Monge \(2020\)](#) analyzed the influence of Covid-19 on crude oil prices. The authors asserted that the oil prices are highly persistent that displayed the mean reverting behavior. Besides, the authors argued that the data prior to Covid-19 pandemic reveals an efficient market. In contrast, after the pandemic outbreak, the oil market becomes inefficient, and this shock will be transitory with having a long-lasting effect.

In case of Saudi Arabia, [Algamdi et al. \(2021\)](#) investigated the impact of Covid-19 death cases on oil prices between January 22 and June 14, 2020. The study used the ARDL modelling approach and concluded that the Covid-19 deaths significantly affect the oil prices in the country. However, the death ratio indirectly affects the crude oil price volatility. Moreover, [Apergis and Apergis \(2020\)](#) studied whether the Covid-19 pandemic and oil price drive the US partisan conflict and asserted that both the oil prices and the Covid-19 significantly help mitigate the US political polarization.

Although, extensive literature is available that empirically investigates the influence of natural resources commodity prices and crude oil or oil prices on economic growth and other indicators. However, to the best of our knowledge, no attempts have been made that empirically discussed and explored the natural resource commodity price volatility and global economic performance in both the pre and post Covid-19 pandemic periods.

3. Data and methodology

3.1. Data and theoretical background

This section of the study emphasizes on the choice of data and econometric procedure employed during empirical investigation. The current study used only two variables for the global representation of the correlation between natural resources commodity prices volatility and economic performance. In this regard, the study opted for the data for both the pre and post Covid-19 pandemic periods. Specifically, we adopted monthly data covering both pre and post pandemic periods from January 01, 2019, to July 01, 2021. The data for the under discussion variables are collected from two sources: the global economic performance data is obtained from the world development indicators ([World Bank, 2021](#)) and the crude oil prices data is extracted from the West Texas Intermediate (WTI, [2021](#)). This study specifically used the crude oil prices in dollars and the global economic performance concerning the variables. The reason for taking the crude oil prices (CROP) is that crude oil is the most traded natural resource and covers 33% primary energy consumption globally ([Wachtmeister et al., 2018](#)). However, this 33% of the crude oil consumption contributes to the economy in the form of industrial production and residential purposes. In this regard, the prices of such natural resources played an essential role in the economic performance of both the energy importing and exporting economies. Besides, unlike other natural resources, the volatility in the crude oil prices largely swings relative to other minerals and natural resources ([Mehrara and Oskoui, 2007](#); [El AnshasyBradley, 2012](#); [Plourde and Watkins, 1998](#)). From a theoretical perspective, it is well established that an increase in natural resources like crude oil in this case, promotes economic growth and enhances revenue of the oil exporting economies and vice versa. But on the other hand, the price hike in natural resources adversely affects and offsets economic performance due to a reduction in industrial production and other economic activities ([Van Eyden et al., 2019](#)). This negative effect of the natural resource commodity price volatility on the global economic performance could be better explained by the theory of irreversible investment, which is pioneered by [Henry \(1974\)](#) and [Bernanke \(1983\)](#). During the Uncertainty, the theory of irreversible investment predicts

that the investors would limit or postpone the expenditures considered irreversible. At the same time, the limiting or postponement in the investment reduces the output on the aggregate level and for those consumers due to the price volatility in the natural resources ([Hamilton, 2003](#)). Therefore, the natural resource commodity price volatility promotes Uncertainty and investors' concerns regarding profitability in the future. This simultaneously enhances the postponement of the investments and expenditures, which consequently adversely affects economic performance.

3.2. The wavelet

The wavelet analysis possesses some advantages in economic research, as instead of the basic classifications of short-term fluctuations and long-term trends used by traditional approaches like error-correction models and co-integration associations, it breakdown a time series into fully specific time scales ([Iqbal et al., 2020](#); [Yan et al., 2021](#)). By collecting data differences, wavelet analysis also allows for retaining essential variables information that might otherwise be lost using standard approaches ([Kim Karlsson et al., 2018](#)). Wavelet analysis reveals how the distinct periodical elements of a time series vary over time by estimating the spectral properties of the time series as a function of time ([Fareed et al., 2020](#)). The wavelet transform enhances a time series into scaled and shifted versions of a function termed as the mother wavelet—which has a restricted duration and spectral band in time ([Aguilar-Conraria et al. \(2008\)](#)). The capacity to execute natural local analysis of a time series is provided by the wavelet transform, in which the wavelets' length varies endogenously: it extends into a lengthy function of wavelet to evaluate movements with low frequency, and it also squeezes into a short function of wavelet to estimate movements with higher frequency. For example, in order to catch rapid changes, very short functions would be appropriate (narrow windows). Simultaneously, very lengthy functions would be appropriate for isolating slow and consistent movements (wide windows). Moreover, another advantage of the wavelet approach is that it could deal with the non-stationarity issue of the time-series, which other approach are mostly unable to tackle ([Sifuzzaman et al., 2009](#)). This is exactly what the wavelet transform can do in an empirical investigation comparatively to other time varying methodologies. The current study joins the strand of [Iqbal et al. \(2020\)](#) and [Yan et al. \(2021\)](#), they also employed a similar empirical strategy for COVID related empirical studies.

A wavelet (ψ) is integral square function with the mean and real value equals zero, that is $\int_{-\infty}^{\infty} \psi(t)dt = 0$. The wavelet function will wiggle via the t-axis executed like a wave. To explore the time-frequency dependence of natural resource commodity prices and economic performance, we used the specific wavelet consisting of both the wavelet power spectrum and wavelet coherence approaches belongs to the Morlet wavelet family premiered by [Goupillaud et al. \(1984\)](#), which could be demonstrated as following:

$$\psi(t) = \pi^{-\frac{1}{4}} \frac{1}{e^{i\omega_0 t}} e^{-\frac{1}{2}t^2} \quad (1)$$

where a wavelet could be performed on the finite time series, i.e., $p(t) = 1, 2, \dots, T$.

Following the Heisenberg uncertainty principle, the Uncertainty is present among the scale and time localizations. A fair selection of the central frequency is the Morlet wavelet $\omega_0 = 6$, this is because this approach adequately balances both the time and scale localization as mentioned by [Rua and Nunes \(2009\)](#).

3.2.1. The continuous type of wavelet transforms

A wavelet is made up of two parameter values, namely, location or time (x) and scale (y). By altering the wavelet, the time parameter "x" defines the exact location of wavelet in time. The scale parameter "z" is

used to regulate how inflated the wavelet is in order to pinpoint different wavelengths. Furthermore, as the scale increases (decreases), the wavelet becomes less (more) compressed, indicating a low (higher) frequency. By transforming the ψ , we initially constructed $\psi_{x,y}$. The transformed equation is provided as Eq. (2) below:

$$\psi_{x,y}(t) = \frac{1}{\sqrt{y}} \psi\left(\frac{t-x}{y}\right), \quad x, y \in \mathbb{R}, y \neq 0 \tag{2}$$

The continuous wavelet transformation may be produced from the wavelet ψ as a function of location or time (x) and scale (y) given a finite-length time series, $W_p(x,y)$ via comparing the p with the entire wavelet family as presented in Eq. (3) below:

$$W_p(x, y) = \int_{-\infty}^{\infty} p(t) \frac{1}{\sqrt{y}} \overline{\psi\left(\frac{t-x}{y}\right)} dt \tag{3}$$

where the bar in the priorly mentioned equation indicates the complex conjugation. However, the original time-series $p(t)$ in Eq. (3) can be reconstructed with its corresponding coefficient is provided in Eq. (4) below:

$$p(t) = \frac{1}{C_\psi} \int_0^{\infty} \left[\int_{-\infty}^{\infty} |W_p(x,y)|^2 dx \right] \frac{dy}{y^2} \tag{4}$$

The squared absolute value or the subsequent wavelet power spectrum (WPS) can provide further information about the amplitude (i.e., the largest possible displacement from the equilibrium moved) of a given time-series. The embracing of the WPS is appropriate as it categorized more materials and amplitude of the relevant time variables. The obtained WPS equation is provided in Eq. (5) below:

$$WPS_p(x,y) = |W_p(x,y)|^2 \tag{5}$$

Generally, the wavelet transform works under the following procedures:

3.2.2. The wavelet coherence

Current study also adopts the wavelet coherence approach. Wavelet coherence resembles classical correlations in certain ways, but it differs in that it depicts any correlation of two time series, i.e., $p(t)$ and $q(t)$ in a combined time-frequency based causal relationship. The cross wavelet transforms of the two time series $p(t)$ and $q(t)$ could be described in Eq. (6) below:

$$W_{pq}(x,y) = W_p(x,y) \overline{W_q(x,y)} \tag{6}$$

where $W_p(x,y)$ indicates the cross wavelet transform for the first time series [$p(t)$] and. $W_q(x,y)$

Indicates the cross wavelet transform for the second time series [$q(t)$] as mentioned by Torrence and Compo (1998). These authors mentioned the squared version of the wavelet coherence, which could be described as Eq. (7) below:

$$R^2(x,y) = \frac{|C(y^{-1}W_{pq}(x,y))|^2}{C(y^{-1}|W_p(x,y)|^2)C(y^{-1}|W_q(x,y)|^2)} \tag{7}$$

From the priorly mentioned Eq. (7), the ‘‘C’’ captures the smoothing over the time and scale from 0 to 1, i.e., $0 \leq R^2(x,y) \leq 1$. Additionally, it is noted that when the $R^2(x,y)$ approaches to one (1), this indicates that there exist the correlation between the two time series at a specific scale, which is further surrounded by the thick black line (contour), and signified by the red color. However, if the $R^2(x,y)$ approaches zero (0), it indicates that there is no correlation among the two time-series, which depicted by the blue color.

In addition to the prior, there is no specific differentiation for the negative or positive correlation while estimation the $R^2(x,y)$ value.

Hence, the Torrence and Compo (1998) theory assists by detecting the variance in the wavelet coherence through the deferrals indications in the wavering of both the time series. The differentiation in the wavelet coherence phase is provided in Eq. (8) below:

$$\varphi_{pq}(x,y) = \tan^{-1} \left(\frac{L\{C(y^{-1}W_{pq}(x,y))\}}{O\{C(y^{-1}W_{pq}(x,y))\}} \right) \tag{8}$$

From the priorly mentioned Eq. (8), the L and O are the lag operators, that represents the imaginary operator and the real part operator, respectively. Here, the equation refers two dimensional plot, which represents the wavelet coherence difference results. The results could be interpreted as the horizontal axis indicates the time dimensions, while the vertical axis depicts the frequency in the wavelet coherence graphical presentation. Furthermore, a lower frequency indicates a greater scale. In areas of time-frequency domain where two series co-vary, the wavelet coherence can be used to find them. Furthermore, the red color implies a strong relationship between series, whilst the blue color signifies a weaker relationship among the time variables. With no connection between the series, the colder areas away from the significant region indicate about time and frequency. The lag and lead phase connection between the studied variables is depicted in the form of an arrow in the wavelet graphical displays. A co-movement across two time variables at a certain scale is depicted by the zero phase difference. Furthermore, when the arrows travel to the right (left), the time series are in phase (anti-phase). Whenever the two series have been in phase, it means that both the variables are moving in the same direction, whereas opposing anti-phase means they are moving in the opposite way. Further, an arrow going left-up or right-down on a wavelet coherence schematic graph indicates that the first variable is dominating the other variable. On the contrary, when the arrows are heading towards left-down, the second variable lead the first one.

3.3. Frequency domain causality test (spectral BC causality test)

After identifying the volatility and the correlation among the two time series via employing the wavelet power spectrum and wavelet coherence approaches, we also checked for the granger causal association between the global economic performance and natural resource commodity price volatility. Therefore, we employed the time and frequency causality tests to examine the possible causalities between the variables of interest. The Toda and Yamamoto causation test provided by the Toda and Yamamoto (1995) could be used if the time series variables are integrated of order zero, one, or two, in contrast to the Granger causality test established by Granger (1969). Besides, even if the time variables are not co-integrated, the Toda and Yamamoto (1995) causality test could be used. We may do vector autoregressive (VAR) estimates in levels using the Toda and Yamamoto causation test, irrespective of whether the time series have or not the same integration order. As a result, there will be no dimensionality reduction since the disparity of the time series data is prevented. Using the Toda and Yamamoto causality techniques, we removed the pre-test bias problem while examining the causal relationship between global economic performance and natural resource commodity price volatility. The Toda and Yamamoto (1995) causality test could be presented in the standard equation form as Eq. (9) below:

$$y_t = \alpha + \beta_1 y_{t-1} + \dots + \beta_p y_{t-p} + \dots + \beta_p + d y_{t-(p+d)} + \varepsilon_t \tag{9}$$

where the left hand side (LHS) (y_t) is a vector of k variables, α represents the intercept, β 's indicates the matrix parameters and the ε_t signifies the residual term of the equation, and finally, the t in the subscript represents the time period of the adopted series.

The major distinction among the time-domain and frequency-domain approaches would be that the time-domain method tells us when a particular variation occurs within a time series, whereas the frequency-domain technique quantifies the magnitude of that

fluctuation. The earlier studies of Granger (1969), Geweke (1982), and Hosoya (1991) proposed measures and testing techniques for frequency-domain causality tests. Where the Geweke (1982) used the Wald testing approach to decompose the spectral density and provided a causality test at a specific frequency. Breitung and Candelon (2006) proposed a granger causality that incorporates both the short-term and long-term prediction at a certain pre-specified frequency, consistent with earlier work by Geweke (1982) and Hosoya (1991). This research tries to apply Breitung and Candelon's (2006) test technique to see whether there is a spectral causal connection among financial risk and economic risk. The opted procedure could be step by step explained as following.

We assume that $X_t = [x1_t, x2_t]$, where the LHS (X_t) is a two-dimensional vector of the stationary and endogenous variables determined in the finite time i.e., $t = 1, 2, \dots, T$. This study assumes that the X_t holds a VAR of finite-orders, which is presented in Eq. (10) below:

$$\Theta(L) X_t = \varepsilon_t \tag{10}$$

where Eq. (10) reveals that $\Theta(L)$ is a 2-by-2 lag polynomial of order p , which can be presented as, $\Theta(L) = I - \Theta_1 L^1 - \dots - \Theta_p L^p$ with the $L^k X_t = X_{t-k}$. Whereas the error term is assumed to be the white noise with $E(\varepsilon_t) = 0$ and $(\varepsilon_t \varepsilon_t') = \Sigma$. Here, Σ is positive definite and symmetric. In consistency to the Breitung and Candelon's (2006) study, this study did not consider any of the deterministic term in Eq. (10) in order to easily provide the presentation.

As priorly mentioned that Σ is positive definite and symmetric: therefore, there exists a Cholesky decomposition, i.e., $G'G = \Sigma^{-1}$, where the G' assumed the upper triangular matrix and the G is presumed as the lower triangular matrix. In this case, the $E(\eta_t \eta_t') = I$, while $\eta_t = G\varepsilon_t$. With the use of the Cholesky decomposition, the moving averages (MA) could be represented in the following Eq. (11) and Eq. (12) below:

$$X_t = \begin{pmatrix} x1_t \\ x2_t \end{pmatrix} = \Phi(L)\varepsilon_t = \begin{bmatrix} \Phi_{11}(L) & \Phi_{12}(L) \\ \Phi_{21}(L) & \Phi_{22}(L) \end{bmatrix} \begin{bmatrix} \varepsilon_{1t} \\ \varepsilon_{2t} \end{bmatrix} \tag{11}$$

$$= \begin{pmatrix} x2_t \\ x1_t \end{pmatrix} = \Psi(L)\eta_t = \begin{bmatrix} \Psi_{11}(L) & \Psi_{12}(L) \\ \Psi_{21}(L) & \Psi_{22}(L) \end{bmatrix} \begin{bmatrix} \eta_{1t} \\ \eta_{2t} \end{bmatrix} \tag{12}$$

where the above equations reveal that $\Phi(L) = \Theta(L)^{-1}$ and $\Psi(L) = \Phi(L)G^{-1}$, respectively. However, the spectral density of $x2_t$ could be provided by utilizing the aforementioned equations as follows:

$$f_{x2}(\omega) = \frac{1}{2\pi} \left\{ \left| \Psi_{11} \left(\frac{1}{e^{-i\omega}} \right) \right|^2 + \left| \Psi_{12} \left(\frac{1}{e^{-i\omega}} \right) \right|^2 \right\} \tag{13}$$

Based on Eq. (11) and Eq. (12), the volatility in the natural resource commodity prices could be explained as the two uncorrelated moving averages process's summation, which have the power to determine the global economic performance. However, the economic performance's predictive power could be determined at each frequency (ω) by the comparison of the predictive component of the spectrum having the frequency's intrinsic component. Thus, it could be noted that the global economic performance does not actually cause the natural resource commodity price volatility at ω when the factor of prediction concerning natural resources commodity price volatility spectrum at frequency ω is zero. This further encourages the causality measures suggested by Geweke (1982) and Hosoya (1991), which are provided in Eq. (14) and Eq. (15) as following:

$$M_{x1 \rightarrow x2}(\omega) = \log \left[\frac{2\pi f_{x2}(\omega)}{|\Psi_{11}(e^{-i\omega})|^2} \right] \tag{14}$$

$$= \log \left[1 + \frac{|\Psi_{12}(e^{-i\omega})|^2}{|\Psi_{11}(e^{-i\omega})|^2} \right] \tag{15}$$

The above-mentioned Eqs. (14) and (15) concerning the Geweke

(1982) calculation is zero when $|\Psi_{12}(e^{-i\omega})|^2 = 0$. Based on this notion, we presumed that natural resources commodity prices do not causes global economic performance at frequency ω . Besides, the study of Breitung and Candelon (2006) have modified the preceding equations by locating the linear restrictions on the first component coefficients of the VAR model as follows: that is the null hypothesis $M_{x1 \rightarrow x2}(\omega) = 0$ is equivalent to the linear restrictions. i.e., $H_0 : R(\omega)\beta = 0$. Where the $\beta = [\beta_1, \dots, \beta_p]'$ indicates the global economic performance's coefficients, and the $R(\omega)$ from the prior equation could be presented as following:

$$R(\omega) = \begin{bmatrix} \cos(\omega)\cos(2\omega)\dots\cos(p\omega) \\ \sin(\omega)\sin(2\omega)\dots\sin(p\omega) \end{bmatrix} \tag{16}$$

The F-statistics for the prior Eq. (16) could approximately be distributed as $F(2, T - 2p)$ for $\omega \in (0, \pi)$. While two (2) is the restriction number, and 'T' represents the observation number which are utilized for the VAR model of order p estimation.

Moreover, while analyzing the frequency domain causality, Although the time horizon is not significant, the frequency method offers distinct benefits over the time-domain technique. In the short series investigations, for example, a seasonality may be relevant, and the frequency domain enables such fluctuations to be eliminated. Furthermore, the frequency-domain method enables us to detect non-linearities and causality cycles, i.e., causation at multiple wavelengths (high and low frequencies). To discover plausible information on causality patterns among natural resource commodity price and global economic performance, we utilise the spectral Breitung and Candelon (2006) causation method.

4. Results and discussion

4.1. Descriptive statistics

We begin our analysis by estimating the descriptive statistics of the data. In an empirical investigation, estimating the descriptive statistics is important as it summarizes the whole data. The current study has adopted two variables, i.e., natural resource commodity price represented by 'CROP' and the global economic performance (GLEP). Regarding the descriptive statistics, the mean value for the CROP is US\$ 51.519. While the median value is reported more than the mean value, it accounted for US\$ 54.07. The range value revealed a greater difference, ranging from the minimum value of US\$ 18.84 to the maximum value of US\$ 75.93. This indicates the higher value of the deviation from the mean value of the CROP. Specifically, the standard deviation value of the CROP is US\$ 13.02, which shows the average deviation of each observation from the mean value. Concerning the GLEP, the index shows the mean value of -0.803 and the median value of -2.058. However, there is a substantial difference between the minimum and maximum GLEP index values. The minimum and the maximum values are accounted for -4.044 and 8.013, respectively. This difference in the range values indicates the higher value of the deviation from the mean value. Hence, the standard value obtained on average for each observation is accounted for 3.406 deviations.

4.2. Global economy in the pre and post Covid-19 era

There is significant evidence demonstrating that Covid-19, after its emergence, adversely affects global economic performance. This results in reducing production and manufacturing activities, decreasing income, and rising unemployment, among other issues. However, some of the sources such as the IMF, World Bank, and the OECD, among others, provide the current and predicted economic growth for the year 2022, which are discussed as follows.

4.2.1. Deviation of output from pre-pandemic projections

With reference to Fig. 1, all the countries across the globe perform

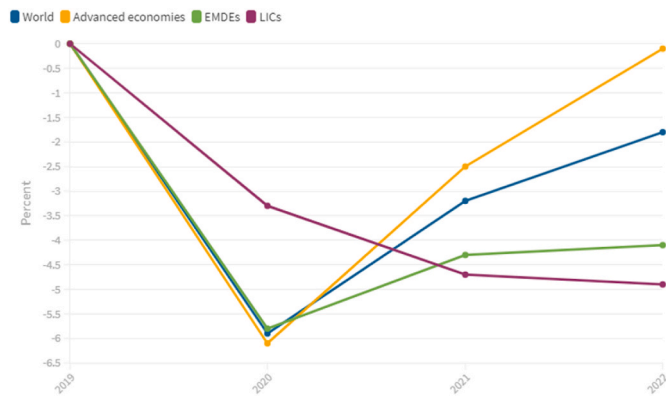


Fig. 1. Deviation of output from pre-pandemic projections. Source: World Bank (2021).¹¹

negatively in response to the emergence of the Covid-19 pandemic. As can be clearly seen from the figure that the global economic growth falls negatively and drops to -6% for the advanced economies and -5.8 and -5.7% growth for the world and emerging market and developing economies (EMDEs), respectively. Besides, the lower income economies (LIC) are faced a smaller shock than those of developed nations. Furthermore, the advanced economies have been settled and start the growth again at the pre-Covid-19 pandemic phase from 2020 last months, and it is expected that these developed economies will retain the same pre-pandemic growth in 2022. However, the EMDEs also follow the path of regaining economic growth from the end of 2020. While the LICs are still facing negative economic growth but at a slower phase than the earlier late 2019 and early 2020.

4.2.2. Global growth has lost momentum

Before the COVID-19 epidemic, activity statistics remained soft, although survey indices in manufacturing and services had begun to stabilize or improve, as shown in the Fig. 2. Financial circumstances had also improved due to measures to loosen monetary policy and lessen trade policy conflicts. According to preliminary estimates, global GDP growth dropped even more in 2019s fourth quarter, to just over 2.50% (on a PPP basis), with strikes, social chaos, and natural catastrophes hamper activities in most of the nations (OECD, 2020). In the US, growth stayed close to the trend. At the same time, demand dropped sharply in Japan after the consumers tax hike in October and deteriorated in economies heavily impacted by global trade slowdowns, such as Germany. Many emerging market countries' developments slowed, with China's GDP growth falling and India's investment being hampered by

huge non-performing loans and over-leveraged corporate balance sheets. Despite continuing gains from the steady employment, industrial production remained stagnant in late 2019, and consumer spending growth has been slowed down. The rate of decrease in worldwide auto sales decreased over 2019. Still, demand has plummeted again, with initial statistics indicating a monthly decline of 10% in January 2020, with a 20% drop in China.

4.2.3. Government priorities to recover from Covid-19

As discussed earlier, almost all the countries in the world face downfall economically with the fall in the global GDP growth to negative. However, after the Covid-19 peak period, economies have started recovery based on their priorities. Fig. 3 shows the priorities of governments' efforts across the globe to achieve the pre-pandemic conditions. In this regard, about 78% of the governments have attempted to restore growth to the pre-pandemic period. However, 63% of the economies have made efforts to recover the most vulnerable, 46–47% of the governments have focused on providing employment opportunities to the lower income population. Additionally, some of the countries, i.e., 30%, have started efforts for debt sustainability. Besides, other countries have also started an initiative for digitalization and innovation to combat future epidemics and protect the general public from such sufferings (Shahzad et al., 2022).

4.3. Wavelet power spectrum

Several time series in economics and other fields have statistics that are nonstationary. Whereas the series might incorporate dominating periodic signals, the amplitude and frequency of these signals might change with time. In this regard, the wavelet coherence technique is used to investigate the co-movement amongst global economic performance and natural resource commodity price volatility, which is a critical goal for governors and researchers in the recent pandemic period. Since the wavelet coherence technique integrates time and frequency domain-based causation methods, this allows the current research study to discover both the short-run and long-run relationships between global economic performance and natural resources commodity price volatility. It is feasible to evaluate the level of co-movement at various frequencies across time using wavelet analysis. These previously mentioned characteristics are the wavelet method's distinguishing characteristics above other previously proposed causality methods (Yan et al., 2021).

In the current study, to investigate the behavior of the global economic performance and natural resource commodity prices and to capture the time-frequency dependence of the global economic performance and over the period from January 01, 2019, to July 01, 2021,

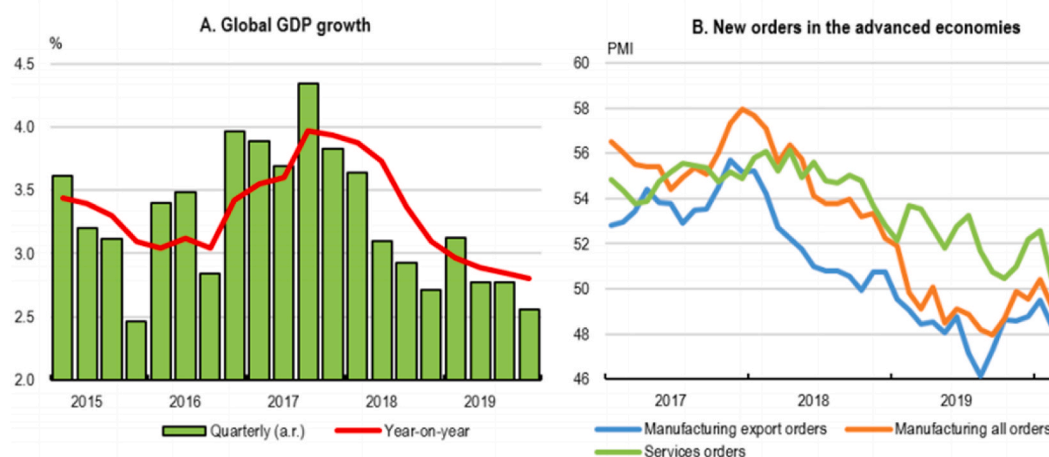


Fig. 2. Global GDP growth and new orders in advanced economies. Source: OECD (2020).

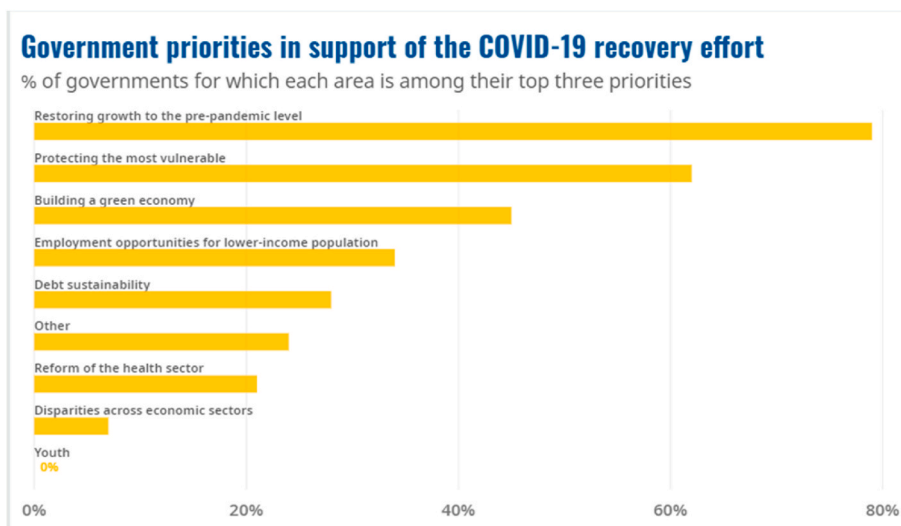


Fig. 3. Government priorities in support of the Covid-19 recovery effort. Source: OECD (2021)²¹

both the wavelet approaches, i.e., wavelet power spectrum and the wavelet coherence approaches are taken into consideration to fill this gap in the existing literature. With reference to Fig. 4, 5 and 6, the white curve corresponds to the cone of influence refers the boundary edge below which the wavelet power is insignificant and hard to incorporate. The dark black outlines (contour) represent the wavelet power spectrum, which is significant at the 5% level, with Monte Carlo simulations used to produce significant test results. The color refers to the power spectrum contrasts from red to blue. The red color represents strong interrelation, and the blue indicates the no or low interrelation in the variable(s) across the time (Kirikkaleli, 2020; Fareed et al., 2020).

With reference to Fig. 1, it can be seen that the natural resource commodity price (CROP) is vulnerable between the Covid-19 peak periods, i.e., from November 2019 to August 2020, at six and eight quarters' scale. Additionally, the vulnerability of the CROP is also observed between February and April 2020 but for the short run at two quarter

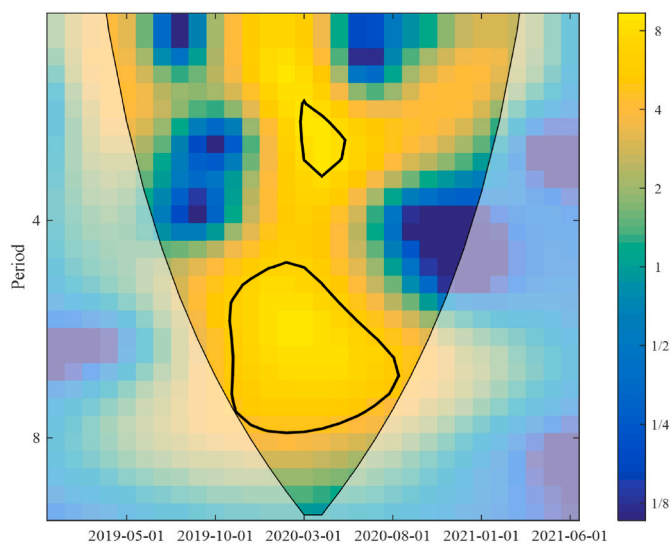


Fig. 4. Wavelet Power Spectrum for crop.

scale. Thus, it could be concluded that vulnerability in the CROP is found during the initial stage and the peak period of the Covid-19, while the weaker vulnerability has been observed in the pre-Covid-19 pandemic period. With reference to Figure-2, although the black curve referring to the cone illustrates the significance level of 5%. However, no vulnerability has been observed in the global economic performance in both the pre and post Covid-19 pandemic periods.

4.4. Wavelet coherence

Concerning the wavelet coherence graphical display, the horizontal axis represents time, while the vertical line represents frequency (the lower the frequency, the larger the scale). The wavelet coherence identifies regions in time-frequency spaces where the two time series covary. Hotter color (i.e., red) indicate places with a significance interdependence, whereas cooler the color (i.e., blue) indicate less interaction of the time series variables. Beyond the important areas, cold zones reflect time and frequencies without any dependency on the series. Additionally, an arrowhead in the wavelet coherence graphs shows the lead/lag phase relationships between the investigated series. A zero phase difference indicates that the two time series are moving in the same direction at a specific scale. When the time variables are in phase,

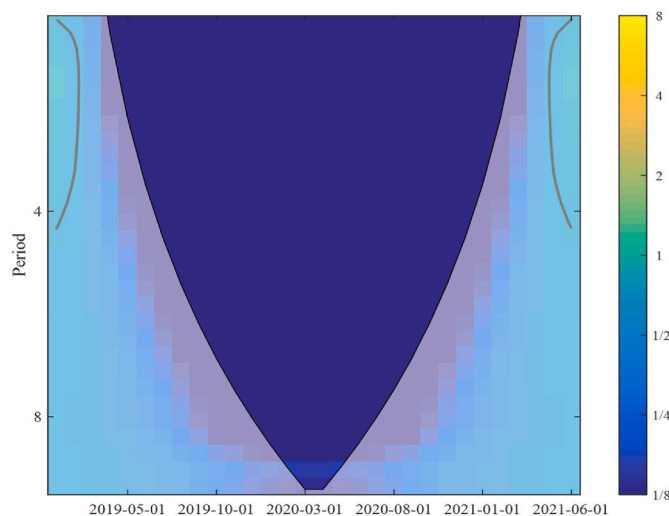


Fig. 5. Wavelet power spectrum for GLEP

¹ Available at: <https://www.worldbank.org/en/news/feature/2021/06/08/the-global-economy-on-track-for-strong-but-uneven-growth-as-covid-19-still-weighs>.

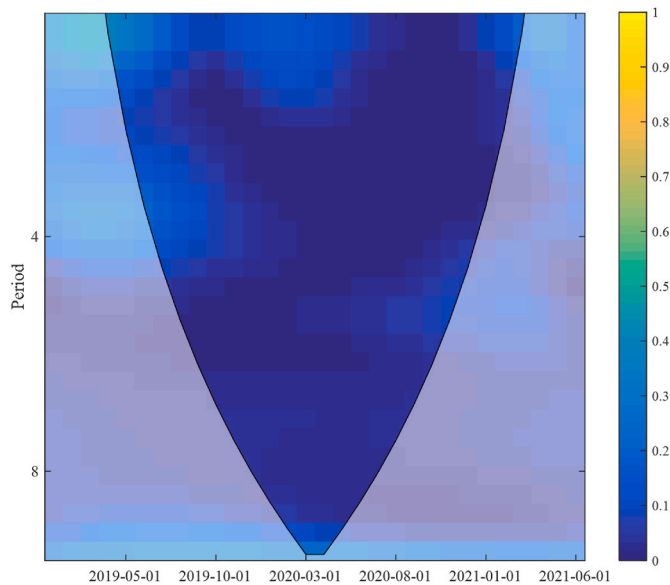


Fig. 6. Wavelet coherence between crop and GDP

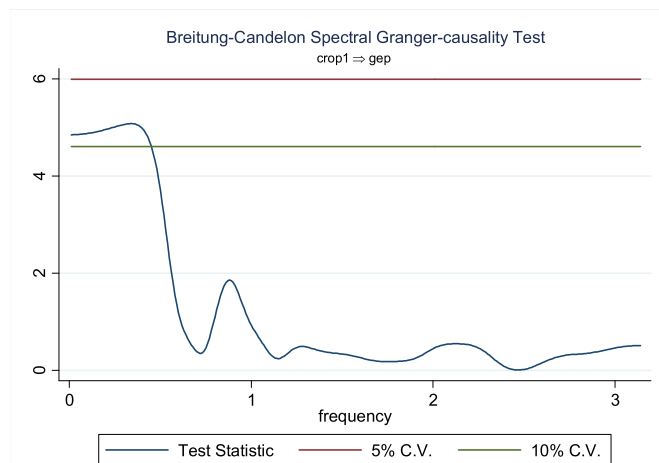


Fig. 7. Causality.

the arrows are pointing to the right. However, when the time variables are in anti-phase, the arrows are heading toward left. Moreover, if the arrows are heading to the right-down or left-up, it indicates that the first variable is leading. However, if the arrows are heading toward right-up or left-down, this indicates that the second variable is leading the other variable.

With reference to Fig. 6, 7, the wavelet coherence graphical displays cold colors across the selected time period. Therefore, no specific or significant causal association has been observed between the global economic performance and natural resource commodity price volatility at any scale or frequency. The results of this study showed consistency to the earlier findings of Bashar et al. (2013) for Canada and Hooker (1996). These studies demonstrate that the natural resources commodity price volatility does not affect macroeconomic performance. However, Uncertainty creates panic that adversely affects economic and production activities. Which further contributes to affect economic performance.

4.5. Causality test

When the time series variables are integrated of orders $I(0)$, $I(1)$, or $I(2)$, the frequency-domain causality test developed by Toda and Yamamoto (1995) gives efficient estimates. Consequently, even if the time series variables are not cointegrated, the Toda and Yamamoto causation test may be applied. As a result, this test is appropriate for use, and the projected results are given in Figure-7. The Breitung-Candelon (BC) spectral Granger causality test also gives the causal link in all runs, including the long-run, medium-run, and short-run. The horizontal red line, on the other hand, indicates the connection between the variables at a 5% level of significance. Thus, it could be clearly observed that under discussion figure that there is no causal association between the natural resource commodity price volatility and global economic performance in the medium and the short-run. However, a slight causality running from the CROP towards global economic performance has been detected but only in the long run.

4.6. Discussion

Before the emergence of Covid-19 pandemic, economies and natural resources market was rapidly growing at a steady phase. However, after the contagious pandemic outbreak, each economy across the globe has suffered due to lock-down and postponement of economic activities. Concerning empirical estimations of current research, like the previous empirical studies, this study also found that the natural resources price is volatile across the Covid-19 pandemic and high vulnerability is observed especially in the Covid-19 peak period (where the new Covid-19 cases and Covid-19 death ratio were at peak). As described by earlier studies (Zhang, 2021; Albulescu, 2020; Gil-Alana and Monge, 2020; Narayan, 2020; Devpura and Narayan, 2020), the Covid-19 pandemic creates volatility in the natural resources, especially in oil prices. Although, Covid-19 contributes greatly to the crude oil price volatility. However, it is not the only reason, many other factors significantly influences oil market price and oil stock price. Such factors include the trade war between Russia and Saudi Arabia, supply shock (Bourghelle et al., 2021), and negative oil price news (Narayan, 2020). Besides, the estimated results also showed no association between natural resources commodity price volatility and the global economic performance, which are consistent with the earlier findings (Bashar et al., 2013; Hooker, 1996). Prior to the Covid-19 emergence, these studies demonstrate that the natural resources commodity price volatility does not affect a country's macroeconomic performance. However, it is Uncertainty which creates panic and adversely affects economic and production activities. Which further contributes to affect economic performance of the country. Furthermore, evidence unveils that this shock will be transitory and will have a long lasting effect on the economy (Gil-Alana and Monge, 2020). Thus, the causal association is expected in the long-run, for which further research is required.

Moreover, as mentioned by Figure-1-2-3, the slowdown in manufacturing, trade, investment, economic growth, and services sector are greatly affected by the Covid-19 pandemic. Volatility in natural resources as validated by this study, is also influenced by Covid-19 pandemic. Since most industrial and economic activities are highly related and responsive to crude oil prices, volatility in natural resources price could also contribute to the destruction of such sectors. However, further research could polish the specific influence of natural resources on each sector as mentioned above.

5. Conclusion and policy implications

The question of whether natural resources are a curse or a blessing for an economy has been extensively studied and evidence is provided against the characteristics of a country or region. Still, the question regarding volatility in natural resources prices remained the topic of interest for the scholars and policy-makers. Currently, the emergence of

² Visit: <https://www.oecd.org/coronavirus/en/themes/global-economy>.

Covid-19 creates a global panic that results in the slowdown of global demand for natural resource commodities due to the lockdown environment. However, this lockdown in most of the world's economies reduced various production, transportation, manufacturing, and other economic activities, affecting economic growth. Besides, reduction in the global natural resource commodities caused Uncertainty and reduced the natural resources commodity prices (for instance, crude oil price) in the peak period of the Covid-19 pandemic. Regardless of the efforts made for the relationship of natural resources and economic performance, the specific area of the volatility of natural resource commodity prices and global economic performance remained unexplored in the pre and post Covid-19 pandemic. Therefore, the current study investigated the relationship between natural resource commodity prices and global economic performance from January 01, 2019, to July 01, 2021. The selected time period covers both the pre and post Covid-19 pandemic periods.

For an empirical investigation of the natural resource commodity price and global economic performance, current study adopted the wavelet power spectrum and wavelet coherence approaches, which considered both the short-term and the long-term causal association between time series. The empirical findings of the wavelet power spectrum suggest significant vulnerabilities only in the natural resource commodity price. This further indicates that natural resource commodity prices are more volatile in the Covid19 pandemic peak period. However, no vulnerability has been found in the global economic performance across the selected time span. Moreover, the wavelet coherent approach's empirical findings reveal no significant causal association between the under discussion variables in the selected time period. Besides, current study also utilized the Breitung-Candelon spectral Granger causality test, which also showed no causal association among the time series variables. However, further research is required for an extensive comparison of pre and post Covid-19 pandemic over the dataset of longer period.

Based on the empirical findings, the current study recommends some practical policy implications that need an urgent implementation to recover the economy and tackle natural resources commodity price volatility. Firstly, policy must be designed to regulate natural resources price freezing or ceiling for at least a shorter time. Secondly, natural resources hedging could be a remedial measure to overcome volatility in natural resources in both short and long-run. Moreover, most countries across the globe still highly depend upon traditional energy sources for industrial and manufacturing activities, which require more consumption of natural resources. However, this increases demand for natural resources, affecting the price level of natural resources such as oil and natural gas. Therefore, policies must be designed regarding promoting renewable energy sources and technological innovation for efficient and sustainable use of natural resources and tackling natural resource price volatility.

Besides the priorly mentioned empirical findings, this research study is held limitations. Like the earlier mentioned studies, this study also adopted crude oil price in terms of natural resources price volatility. However, natural resources are not limited only to crude oil prices, but also include coal price, natural gas price and other minerals price such as gold, silver, etc. Furthermore, this study utilized monthly data for an empirical investigation, which covers only 30 months. However, data for a longer period could provide consistent results. Therefore, future researchers and scholars are directed to adopt a wide range of natural resources to extensively examine natural resources commodity price volatility and its impact on economic performance. Future research could also consider comparative studies of the developing and developed world. Moreover, an extensive dataset consideration would provide consistent results for these regions.

CRedit authorship contribution statement

Li Sun: Supervision, Project administration, Funding acquisition,

Methodology, Software. Yang Wang: Formal analysis, Conceptualization, Writing – original draft, Data curation.

Acknowledgment

The authors gratefully acknowledge the financial support provided by the major project of Philosophy and Social Sciences key research base of Jilin University "Research on bilateral cross border e-commerce, trade structure change and consumer behavior between China and Japan" (2019XXJD15).

The project of Labor Relations Research Center of Jilin University "Research on the experience and enlightenment of international typical countries in coordinating labor relations" (2018LD010) Youth Academic backbone program of philosophy and Social Sciences research base of Jilin University "Research on the impact of consumption upgrading on the transformation and upgrading of China's foreign trade in the context of trade frictions"(2019FRGG06).

References

- Adebayo, T.S., Akinsola, G.D., 2021. Investigating the causal linkage among economic growth, energy consumption and CO2 emissions in Thailand: an application of the wavelet coherence approach. *Int. J. Renew. Energy Dev.* 10.
- Aguiar-Conraria, L., Azevedo, N., Soares, M.J., 2008. Using wavelets to decompose the time-frequency effects of monetary policy. *Physica A* 387, 2863–2878. <https://doi.org/10.1016/j.physa.2008.01.063>.
- Albulescu, C., 2020. Do COVID-19 and Crude Oil Prices Drive the US Economic Policy Uncertainty?. 07591 arXiv preprint arXiv:2003.
- Algami, A., Brika, S.K.M., Musa, A., Chergui, K., 2021. COVID-19 deaths cases impact on oil prices: probable scenarios on Saudi Arabia economy. *Frontiers in Public Health* 9, 6. <https://doi.org/10.3389/fpubh.2021.620875>.
- Apergis, E., Apergis, N., 2020. Can the COVID-19 pandemic and oil prices drive the US Partisan Conflict Index. *Energy Research Letters* 1, 13144. <https://doi.org/10.46557/001c.1314>.
- Arain, H., Sharif, A., Akbar, B., Younis, M.Y., 2020. Dynamic connection between inward foreign direct investment, renewable energy, economic growth and carbon emission in China: evidence from partial and multiple wavelet coherence. *Environ. Sci. Pollut. Res. Int.* 27, 40456–40474. <https://doi.org/10.1007/s11356-020-08836-8>.
- Atil, A., Nawaz, K., Lahiani, A., Roubaud, D., 2020. Are natural resources a blessing or a curse for financial development in Pakistan? The importance of oil prices, economic growth and economic globalization. *Resour. Pol.* 67, 101683. <https://doi.org/10.1016/j.resourpol.2020.101683>.
- Bashar, O.H., Wadud, I.M., Ahmed, H.J.A., 2013. Oil price uncertainty, monetary policy and the macroeconomy: the Canadian perspective. *Econ. Modell.* 35, 249–259. <https://doi.org/10.1016/j.econmod.2013.07.007>.
- Bernanke, B.S., 1983. Irreversibility, Uncertainty, and cyclical investment. *Quart. J. Econ.* 98 (1), 85–106.
- Bourghelle, D., Jawadi, F., Rozin, P., 2021. Oil price volatility in the context of Covid-19. *Int. Econ.* 167, 39–49. <https://doi.org/10.1016/j.inteco.2021.05.001>.
- Breitung, J., Candelon, B., 2006. Testing for short-and long-run causality: a frequency-domain approach. *J. Econom.* 132, 363–378. <https://doi.org/10.1016/j.jeconom.2005.02.004>.
- Brown, S.P., Yücel, M.K., 2002. Energy prices and aggregate economic activity: an interpretative survey. *Q. Rev. Econ. Finance* 42, 193–208. [https://doi.org/10.1016/S1062-9769\(02\)00138-2](https://doi.org/10.1016/S1062-9769(02)00138-2).
- Cevik, N.K., Cevik, E.I., Dibooglu, S., 2020. Oil prices, stock market returns and volatility spillovers: evidence from Turkey. *J. Pol. Model.* 42, 597–614. <https://doi.org/10.1016/j.jpmodel.2020.01.006>.
- Devpura, N., Narayan, P.K., 2020. Hourly oil price volatility: the role of COVID-19. *Energy RESEARCH LETTERS*. <https://doi.org/10.46557/001c.13683>.
- Doğan, B., Ben Jebli, M., Shahzad, K., Farooq, T.H., Shahzad, U., 2020. Investigating the Effects of Meteorological Parameters on COVID-19: Case Study of New Jersey, United States. *Environ. Res.* 191. <https://doi.org/10.1016/j.envres.2020.110148>.
- Ebrahim, Z., Inderwildi, O.R., King, D.A., 2014. Macroeconomic impacts of oil price volatility: mitigation and resilience. *Front. Energy* 8, 9–24. <https://doi.org/10.1007/s11708-014-0303-0>.
- El Anshasy, A.A., Bradley, M.D., 2012. Oil prices and the fiscal policy response in oil-exporting countries. *J. policy model.* 34, 605–620. <https://doi.org/10.1016/j.jpmodel.2011.08.021>.
- Fareed, Z., Iqbal, N., Shahzad, F., Shah, S.G.M., Zulfikar, B., Shahzad, K., Hashmi, S.H., Shahzad, U., 2020. Co-variance nexus between COVID-19 mortality, humidity, and air quality index in Wuhan, China: new insights from partial and multiple wavelet coherence. *Air Qual. Atmos. Heal.* 13, 673–682. <https://doi.org/10.1007/s11869-020-00847-1>.
- Geweke, J., 1982. Measurement of linear dependence and feedback between multiple time series. *J. Am. Stat. Assoc.* 77, 304–313. <https://doi.org/10.1080/01621459.1982.10477803>.
- Gil-Alana, L.A., Monge, M., 2020. Crude oil prices and COVID-19: persistence of the shock. *Energy Research Letters* 1, 13200. <https://doi.org/10.46557/001c.13200>.

- Goupillaud, P., Grossmann, A., Morlet, J., 1984. Cycle-octave and related transforms in seismic signal analysis. *Geoprospection* 23, 85–102. [https://doi.org/10.1016/0016-7142\(84\)90025-5](https://doi.org/10.1016/0016-7142(84)90025-5).
- Granger, C.W., 1969. Investigating causal relations by econometric models and cross-spectral methods. *Econometrica: journal of the Econometric Society* 424–438. <https://doi.org/10.2307/1912791>.
- Guan, L., Zhang, W.-W., Ahmad, F., Naqvi, B., 2021. The volatility of natural resource prices and its impact on the economic growth for natural resource-dependent economies: a comparison of oil and gold dependent economies. *Resour. Pol.* 72, 102125. <https://doi.org/10.1016/j.resourpol.2021.102125>.
- Hamilton, J.D., 2003. What is an oil shock? *J. Econom.* 113, 363–398. [https://doi.org/10.1016/S0304-4076\(02\)00207-5](https://doi.org/10.1016/S0304-4076(02)00207-5).
- Hathroubi, S., Aloui, C., 2020. Oil price dynamics and fiscal policy cyclicality in Saudi Arabia: new evidence from partial and multiple wavelet coherences. *Q. Rev. Econ. Finance*. <https://doi.org/10.1016/j.qref.2020.12.002>.
- Hayat, A., Tahir, M., 2021. Natural resources volatility and economic growth: evidence from the resource-rich region. *J. Risk Financ. Manag.* 14, 84. <https://doi.org/10.3390/jrfm14020084>.
- Henry, C., 1974. Investment decisions under Uncertainty: the “irreversibility effect”. *Am. Econ. Rev.* 64, 1006–1012.
- Hooker, M.A., 1996. What happened to the oil price-macroeconomy relationship? *J. Monetary Econ.* 38, 195–213. [https://doi.org/10.1016/S0304-3932\(96\)01281-0](https://doi.org/10.1016/S0304-3932(96)01281-0).
- Hosoya, Y., 1991. The decomposition and measurement of the interdependency between second-order stationary processes. *Probab. Theor. Relat. Field* 88, 429–444. <https://doi.org/10.1007/BF01192551>.
- Iqbal, N., Fareed, Z., Shahzad, F., He, X., Shahzad, U., Lina, M., 2020. The nexus between COVID-19, temperature and exchange rate in Wuhan city: new findings from partial and multiple wavelet coherence. *Sci. Total Environ.* 729, 138916. <https://doi.org/10.1016/j.scitotenv.2020.138916>.
- Kartal, M.T., 2020. The effect of the COVID-19 pandemic on oil prices: evidence from Turkey, 1. *Energy Research Letters*. Available at: SSRN: <https://ssrn.com/abstract=3773537>.
- Katoka, B., Dostal, J.M., 2021. Natural resources, international commodity prices and economic performance in sub-saharan africa (1990–2019). *Journal of African Economies*. <https://doi.org/10.1093/jae/ejab014>.
- Kim Karlsson, H., Li, Y., Shukur, G., 2018. The causal nexus between oil prices, interest rates, and unemployment in Norway using wavelet methods. *Sustainability* 10, 2792. <https://doi.org/10.3390/su10082792>.
- Kirikaleli, D., 2020. Does political risk matter for economic and financial risks in Venezuela? *Journal of Economic Structures* 9, 1–10. <https://doi.org/10.1186/s40008-020-01888-5>.
- Lardic, S., Mignon, V., 2006. The impact of oil prices on GDP in European countries: an empirical investigation based on asymmetric cointegration. *Energy Pol.* 34, 3910–3915. <https://doi.org/10.1016/j.enpol.2005.09.019>.
- Lardic, S., Mignon, V., 2008. Oil prices and economic activity: an asymmetric cointegration approach. *Energy Econ.* 30, 847–855. <https://doi.org/10.1016/j.eneco.2006.10.010>.
- Mehra, M., Oskoui, K.N., 2007. The sources of macroeconomic fluctuations in oil exporting countries: a comparative study. *Econ. Modell.* 24, 365–379. <https://doi.org/10.1016/j.econmod.2006.08.005>.
- Millia, H., Adam, P., Saenong, Z., Balaka, M.Y., Pasrun, Y.P., Wali, A.R., 2020. The influence of crude oil prices volatility, the internet and exchange rate on the number of foreign tourist arrivals in Indonesia. *Int. J. Energy Econ. Pol.* 10, 280. <https://doi.org/10.32479/ijeep.10083>.
- Mukhtarov, S., Aliyev, S., Zeynalov, J., 2020. The effect of oil prices on macroeconomic variables: evidence from Azerbaijan. *Int. J. Energy Econ. Pol.* 10, 72–80. <https://doi.org/10.32479/ijeep.8446>.
- Narayan, P.K., 2020. Oil price news and COVID-19—is there any connection? *Energy RESEARCH LETTERS*. <https://doi.org/10.46557/001c.13176>.
- OECD, 2020. Coronavirus: the world economy at risk. Organisation for Economic Cooperation and Development. France: Assessment OI. Available at: <https://www.oecd.org/berlin/publikationen/Interim-Economic-Assessment-2-March-2020.pdf>.
- Pandey, V., Talan, A., Mahendru, M., 2021. Studying the psychology of coping negative emotions during COVID-19: a quantitative analysis from India. *Environ. Sci. Pollut. Res.*
- Plourde, A., Watkins, G.C., 1998. Crude oil prices between 1985 and 1994: how volatile in relation to other commodities? *Resour. Energy Econ.* 20, 245–262. [https://doi.org/10.1016/S0928-7655\(97\)00027-4](https://doi.org/10.1016/S0928-7655(97)00027-4).
- Prabheesh, K.P., Garg, B., Padhan, R., 2020. Time-varying dependence between stock markets and oil prices during COVID-19: the case of net oil-exporting countries. *Econ. Bull.* 40, 2408–2418.
- Rahim, S., Murshed, M., Umarbeyli, S., Kirikkaleli, D., Ahmad, M., Tufail, M., Wahab, S., 2021. Do natural resources abundance and human capital development promote economic growth? A study on the resource curse hypothesis in Next Eleven countries. *Resources, Environment and Sustainability* 4, 100018. <https://doi.org/10.1016/j.resenv.2021.100018>.
- Rosnawintang, R., Tajuddin, T., Adam, P., Pasrun, Y.P., 2021. Effects of crude oil prices volatility, the internet and inflation on economic growth in ASEAN-5 countries: a panel autoregressive distributed lag approach. *Int. J. Energy Econ. Pol.* 11, 15. <https://doi.org/10.32479/ijeep.10395>.
- Rua, A., Nunes, L.C., 2009. International comovement of stock market returns: a wavelet analysis. *J. Empir. Finance* 16, 632–639. <https://doi.org/10.1016/j.jempfin.2009.02.002>.
- Sarwar, S., Chen, W., Waheed, R., 2017. Electricity consumption, oil price and economic growth: global perspective. *Renew. Sustain. Energy Rev.* 76, 9–18. <https://doi.org/10.1016/j.rser.2017.03.063>.
- Sarwar, S., Shahzad, K., Fareed, Z., Shahzad, U., 2021. A study on the effects of meteorological and climatic factors on the COVID-19 spread in Canada during 2020. *J. Environ. Heal. Sci. Eng.* <https://doi.org/10.1007/s40201-021-00707-9>.
- Sauter, R., Awerbuch, S., 2003. Oil price volatility and economic activity: a survey and literature review, 28. *IEA research paper*, pp. 550–577.
- Shahbaz, M., Sarwar, S., Chen, W., Malik, M.N., 2017. Dynamics of electricity consumption, oil price and economic growth: global perspective. *Energy Pol.* 108, 256–270. <https://doi.org/10.1016/j.enpol.2017.06.006>.
- Shahzad, K., Farooq, T.H., Doğan, B., Hu, L.Z., 2021. Does environmental quality and weather induce COVID-19: case study of Istanbul , Turkey. *Environ. Forensics* 1–12. <https://doi.org/10.1080/15275922.2021.1940380>, 0.
- Shahzad, U., Ferraz, D., Nguyen, H., Cui, L., 2022. Investigating the spill overs and connectedness between financial globalization, high-tech industries and environmental footprints: Fresh evidence in context of China. *Technol. Forecast. Soc. Chang.* 174, 121205. <https://doi.org/10.1016/j.techfore.2021.121205>.
- Shakoor, A., Chen, X., Farooq, T.H., 2020. Fluctuations in environmental pollutants and air quality during the lockdown in the USA and China: two sides of COVID-19 pandemic. *Air Qual. Atmos. Heal.* 13 <https://doi.org/10.1007/s11869-020-00888-6> Fluctuations.
- Sharif, A., Aloui, C., Yarovaya, L., 2020. COVID-19 pandemic, oil prices, stock market, geopolitical risk and policy uncertainty nexus in the US economy: fresh evidence from the wavelet-based approach. *Int. Rev. Financ. Anal.* 70, 101496. <https://doi.org/10.1016/j.irfa.2020.101496>.
- Sharma, G.D., Ibrahim, M., Shahzad, U., Jain, M., Chopra, R., 2021. Exploring the nexus between agriculture and greenhouse gas emissions in BIMSTEC region : the role of renewable energy and human capital as moderators. *J. Environ. Manag.* 297, 113316. <https://doi.org/10.1016/j.jenvman.2021.113316>.
- Sifuzzaman, M., Islam, M.R., Ali, M.Z., 2009. Application of Wavelet Transform and its Advantages Compared to Fourier Transform.
- Su, C.-W., Huang, S.-W., Qin, M., Umar, M., 2021. Does crude oil price stimulate economic policy uncertainty in BRICS? *Pac. Basin Finance J.* 66, 101519. <https://doi.org/10.1016/j.pacfin.2021.101519>.
- Su, C.-W., Qin, M., Tao, R., Umar, M., 2020. Financial implications of fourth industrial revolution: can bitcoin improve prospects of energy investment? *Technol. Forecast. Soc. Change* 158, 120178. <https://doi.org/10.1016/j.techfore.2020.120178>.
- Toda, H.Y., Yamamoto, T., 1995. Statistical inference in vector autoregressions with possibly integrated processes. *J. Econom.* 66, 225–250. [https://doi.org/10.1016/0304-4076\(94\)01616-8](https://doi.org/10.1016/0304-4076(94)01616-8).
- Torrence, C., Compo, G.P., 1998. A practical guide to wavelet analysis. *Bull Am Meteorol Soc B AM METEOROL SOC* 79, 61–78. [https://doi.org/10.1175/1520-0477\(1998\)079<0061:APGTWA>2.0.CO](https://doi.org/10.1175/1520-0477(1998)079<0061:APGTWA>2.0.CO).
- Van Eyden, R., Difto, M., Gupta, R., Wohar, M.E., 2019. Oil price volatility and economic growth: evidence from advanced economies using more than a century’s data. *Appl. Energy* 233, 612–621. <https://doi.org/10.1016/j.apenergy.2018.10.049>.
- Wachtmeister, H., Henke, P., Höök, M., 2018. Oil projections in retrospect: revisions, accuracy and current Uncertainty. *Appl. Energy* 220, 138–153. <https://doi.org/10.1016/j.apenergy.2018.03.013>.
- Waheed, R., Sarwar, S., Dignah, A., 2020. The role of non-oil exports, tourism and renewable energy to achieve sustainable economic growth: what we learn from the experience of Saudi Arabia. *Struct. Change Econ. Dynam.* 55, 49–58. <https://doi.org/10.1016/j.strueco.2020.06.005>.
- World Bank, 2021. World Development Indicators. <https://databank.worldbank.org/source/world-development-indicators#advancedDownloadOptions>.
- WTI, 2021. West Texas Intermediate. Investing.com. <https://www.investing.com/commodities/crude-oil-historical-data>.
- Yan, Y., Shah, M.I., Sharma, G.D., Chopra, R., Fareed, Z., Shahzad, U., 2021. Can tourism sustain itself through the pandemic : nexus between tourism , COVID-19 cases and air quality spread in the 'Pineapple State' Hawaii. *Curr. Issues Tourism* 1–20. <https://doi.org/10.1080/13683500.2021.1965553>, 0.
- Zhang, Y., 2021. The COVID-19 outbreak and oil stock price fluctuations: evidence from China. *Energy RESEARCH LETTERS*. <https://doi.org/10.46557/001c.27019>.