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Natural resources commodity prices volatility and economic performance: Evidence from China pre and post COVID-19

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\textbf{ABSTRACT}

Volatility in the prices of natural resources particularly in the Covid-19 period is the subject of major concern in recent times. Although many studies have empirically investigated the influence of oil prices on economic growth and Covid-19 on oil prices. However, the current study contributes to the literature by investigating the causal linkage of natural resources commodity prices and economic growth in the pre and post Covid-19 period for China over the period from January 01, 2019, to April 01, 2021. This study employed the wavelet power spectrum, and the wavelet coherence approaches, and the frequency domain causality test, which is known for the causal identification in the long-run, medium-run, and short-run. The empirical findings reveal that the natural resource commodity prices are more vulnerable than the economic performance particularly in the Covid-19 peak period in China. However, the wavelet coherence approach demonstrates that a bidirectional causal association exists between natural resources commodity prices and economic performance at different frequencies and time periods. Additionally, the frequency domain causality test confirms that the natural resource commodity prices volatility significantly causes economic performance only in the medium-run. Based on the empirical findings, this study recommends that innovative technological and precautionary measures must be taken to accommodate or overcome natural disasters in the future, and tackle natural resources commodity prices volatility.

1. Introduction

The dynamic association between natural resource commodity price and economic activities is one of the pointed issues in the literature of macroeconomics. However, after the emergence of the contagious disease named Covid-19 various economic activities such as production, distribution, and lifestyle have been terminated that considerably pushes economic uncertainty in all economies of the world (Baker et al., 2020). The outbreak of this contagious disease is first diagnosed in Wuhan, China in late 2019. Therefore, compared to other economies, China faced an economic downturn and natural resource commodity prices volatility in the first phase due to the locked-down environment. This lockdown environment significantly affects both the economic activities and natural resources demand, such as oil demand. Although, it is well studied that a reduction in natural resource oil prices shrinks the production cost and significantly contributes to economic growth (Narayan et al., 2014). Currently, the global supply lines have been disrupted and aggregate demand has been decreased as a result of the COVID-19 outbreak and the ongoing economic lockdowns (Vidyag and Prabheesh, 2020). The lockdowns resulted in a significant drop in natural resource commodity (such as crude oil) prices on the global market, that is from US$61 on January 02, 2020, to US$12 on April 28, 2020, owing to a substantial fall in oil consumption (Prabheesh et al., 2020). However, this natural resource commodity price decline because of the Covid-19 pandemic along with the plunging economic growth globally raises the concern of the policymakers and scholars to investigate the causal association of economic growth and natural resource commodity price volatility. (see Table 1, Figs. 1–6)
Prior to Covid-19 pandemic outbreak, there are evidence that economic activities were moving at a rapid phase, where the green supply management services and renewable energy consumption were associated to international trade, and also contribute to economic growth (Khan et al., 2021a, 2021b, 2021b). However, after the Covid-19 emergence, these activities are affected that adversely influence economic growth. Also, the higher Covid-19 intensity leads to higher stringent measures which also caused food supply chain disruption (Khan et al., 2020). Generally, the natural resources are the most traded goods across the globe. For instance, one of the natural resource crude oils is the most traded and world largest energy source which provides 33% of the primary energy consumption across the globe (Wachtmeister et al., 2018), which could run most of the sectors in an economy. However, the prices of that commodity like other natural resources prices are volatile and largely swings than the other mineral resources (Mehrara and Oskoui, 2007; El Anshasy and Bradley, 2012; Plourde and Watkins, 1998). Theoretically, it is well-founded that an increase in the natural resources price particularly in the resources exporting economies acts as a catalyst for revenue generation and development. While on the contrary, the natural resources importing economies are facing adverse effect of the natural resources price hike, which decline economic activities, especially in the case of crude oil price hike (Van Eyden et al., 2019). The negative influence of the natural resources’ prices volatility on the economic activities could be generally explained by the irreversible investment theory. The concept of irreversible investment during uncertainty, first proposed by Henry (1974) and Bernanke (1983) – predicts that throughout periods of uncertainty, investors would postpone expenditures they consider irreversible. However, this postponement in the investment declines the aggregate output level and also for the consumers in the wake of natural resources’ price volatility (Hamilton, 2003). Hence, the natural resources’ commodity prices volatility create uncertainty concerning future’s profitability, which results in the postponement of the investment and expenditures, that also hurts the industrial production sector.

Although several empirical methodologies have been observed that deal with the issue of natural resource commodity price or the natural resource commodity price volatility and economic growth for different regions (Prabhesh and Laila, 2020; Baek et al., 2020; Baek and Young, 2020; Mukhtarov et al., 2020). However, the natural resource market such as oil market is uncertain as a result of COVID-19’s interruptions. In this context, it is unclear that how natural resource commodity price volatility affect economic performance in the leading energy importing economy. The need to understand this link is widely documented in the priorly mentioned economics research. However, these methodologies still not clearly mentioned the causal association between the natural resource commodity price volatility and economic performance in the pre and post Covid-19 period.

China has made significant progress in economic growth after broad reforms began in 1978 (Yan et al., 2020). The global economy began to contract after the financial crisis of 2008, however, China’s economy continued to grow at a moderate pace. The economic growth of China is remarkably resilient, leaving plenty of room for dealing with external shocks while still achieving higher-quality development. The government of China has proposed a long-term development strategy that includes not just numeric growth but also qualitative improvements in living standards (Vasie et al., 2020). At the end of 2019, a global pandemic was triggered by the Covid-19 coronavirus outbreak in Wuhan, China. As a consequence, the World Health Organization declared an international emergency on January 31, 2020 (WHO, 2020). Covid-19 has implications in the world economy as well as on financial sectors, as it has in previous crises. Many experts linked the Covid-19 epidemic to the SARS outbreak in 2003. Despite the fact that this can provide helpful information, the two occurrences are vastly different. China now has far more power over the global economy and markets than it had 17 years ago. As per the World Bank data, the share of China in global trade grew to over 14% in 2019 from five percent in 2003. In addition, its MSCI Emerging Markets Index weighting increased to about 35% in 2019 from eight percent in 2003 (Bouiyour and Selmi, 2020; Wen et al., 2020). As a result, the Covid-19 pandemic is causing havoc on China’s economy (Alam and Jones, 2020).

The current study aims to investigate the causal association between natural resource commodity price volatility and economic performance in the pre and post Covid-19 pandemic period for the case of China. Although the literature extensively provides empirical investigations concerning natural resource commodity price and specifically the oil prices and economic growth. However, this area remained unexplored concerning the causal association of natural resource commodity price and economic performance in China. Thus, in view of the ongoing Covid-19 contagious pandemic, it is critical to reexamine this theory.

This study contributes to the existing literature twofold. Firstly, the current study investigates the causal relationship between the natural resource commodity prices volatility and economic performance in the case of China, which remained unexplored. Secondly, the current study considers the pre and post Covid-19 period, which holds importance as China is the leading oil importer and an emerging economy that faces the challenge of the Covid-19 outbreak at the earliest stage. To the best of our knowledge, this study is novel as there is no such study available that examined or analyzed the causal linkage of natural resource commodity price volatility and economic performance in the case of China. Also, the current study consider both the pre and post Covid-19 pandemic periods, which is one of the pioneering roles of this study after the Covid-19 pandemic outbreak. Additionally, the current study used a novel estimating technique, i.e., the wavelet power spectrum approach, the wavelet coherence approach, and the frequency domain causality test, which none of the studies undertake in the case of Covid-19 and these macroeconomic variables in the case of China.

The rest of the study is organized as follows: Section-2 presents a review of the relevant literature; Section-3 provides Methodology used in the study; Section-4 reveals the results and discussion; lastly, Section-5 explains the conclusion of the study and policy implications.

1.1. Literature review

In the modern environmental-economic scenario, well-developed and less-developed nations have great concern about natural resources depletion and price instability. Scholars and researchers have provided extensive literature concerning the natural resources prices volatility and economic performance’s nexus. The earlier literature considered various natural resources price volatility. However, the most recent literature focused more upon the oil prices volatility and economic growth. Such studies include Aloui et al. (2018), Prabhesh and Laila (2020), Baek et al. (2020), Baek and Young (2020), Mukhtarov et al. (2020), Katircioglu et al. (2020), E.I. Cevik et al. (2020), Cevik et al. (2020) pp. 1–23, Charfeddine and Barkat (2020), among others. Most of these studies are concerned with the asymmetric impact of oil price volatility on economic growth and other indicators of economic growth, such as stock market, banking profitability, etc.

Specifically, Aloui et al. (2018) investigated economic growth, oil price, exchange rate, and inflation nexus for Saudi Arabia over the

| Table-1 |
| --- |
| Descriptive statistics and normality test. |
| | GDP | NRCB |
| Mean | 2.50E+13 | 6133.54 |
| Median | 2.50E+13 | 6543.49 |
| Maximum | 2.99E+13 | 8092.46 |
| Minimum | 2.01E+13 | 2369.13 |
| Std. Dev. | 2.80E+13 | 1475.96 |
| Skewness | -0.06E+6 | -0.97E+6 |
| Kurtosis | 2.20E+0 | 3.51E+0 |
| Jarque-Bera | 0.73E+6 | 4.76E+0 |
| Probability | 0.68E+0 | 0.09E+0 |
period from 1969 to 2014. The study used novel Morlet’s wavelet methods including the cross-wavelet power spectrum, continuous wavelet power spectrum, the wavelet coherence, the multiple, and the partial wavelet coherence methods. Examined results asserted that the variables’ association evolves through time and frequency. The results unveil strong but heterogeneous association from the time domain, while strong lead and lag, and significant wavelet coherence from the frequency domain among these variables. Further, the study unveils that the economy is exposed to various global risks including oil market volatility—having a strong negative effect on economic growth. Concerning the asymmetric effects of crude and palm oil on economic growth, Prabheesh and Laila (2020) investigated the 2000–2019 period for Indonesia by using the linear and non-linear autoregressive distributed lag (ARDL) methodology. The results unveil that the effects of oil prices on economic growth are non-linear, whereas the effect of palm oil price volatility is higher than that of petroleum. Moreover, the reduction in the global price market of palm oil negatively affects economic growth. Using the same techniques, Baek et al. (2020) reveal that the oil

![Fig. 1. Seasonal adjustment for GDP](image-url)
price significantly affects economic growth strongly in the short run. Whereas the influence of crude oil is found significant via NARDL in both short and long-run in 31 provinces of China.

In addition, another study by Baek and Young (2020) looks into the nexus of crude oil prices and economic growth while utilizing the quarterly data spanning 1998Q1 to 2017Q2. Using the NARDL approach, the study unveils consistent findings to that of Prabh ees and Lalila (2020), that the oil price volatility asymmetrically affects the economic growth of the oil-exporting economy, i.e., Alaska in both the short-run and the long-run. Concerning the role of oil prices in transition to renewable energy consumption, Mukhtarov et al. (2020) analyzed time-series data throughout 1992–2015 for Azerbaijan. After employing the structural time series models, the estimated outcomes asserted that economic growth positively and significantly affects renewable energy consumption, while oil prices negatively influence renewable energy consumption. This revealed that higher oil prices impede the transition to renewable energy from conventional fossil fuel sources.

The study of Katircioglu et al. (2020) examined the oil prices, inflation, and growth in the bank’s profitability in Turkey. The study constructs two models to identify the direct and indirect effects of oil price volatility on the profitability of banks and reveal that volatility in the oil prices significantly but indirectly affect bank’s profitability via the channel of inflation. Specifically, the oil prices decrease the oil-related business lending and consequently affect the banking sector profitability directly and negatively. For the same country, N.K. Cevik et al. (2020) analyzed oil prices, returns of the stock market, and volatility spillover throughout the 1990–2017 period. After employing the EGARCH modeling approach, the estimated results unveil that the crude oil prices significantly influence the stock market return measured via the Brent benchmark. They also argued that there is no significant spillover effect found for the oil prices.

In the case of major emerging economies, Cevik et al. (2020: pp. 1–23) illustrates the strong correlation between energy prices and economic activities. Further, the study argued that a change in the crude oil prices is linked to the changes in production cost and economic activities that also influence crude oil and energy demand. After employing the frequency domain causality methods, this study uncovers that there is a bidirectional causal association between crude oil prices and economic activities. However, it is noted that only the negative oil price shocks decrease economic activities. In the case of the oil-dependent economy, Charfeddine and Barkat (2020) employed the A-B structural vector autoregressive (AB – SVARX) and the NARDL models to identify the asymmetric impact of oil prices and oil and gas (O&G) revenue on economic growth and diversification both in the short and long-run. The estimated outcomes reveal that the real GDP and non-oil GDP are highly responsive to the negative shock in the real oil prices and O&G revenue than the positive shocks in the short term. While the impact is reported to be effective only till the three quarters. However, in the long run, the positive shocks are highly influential on economic activities.

In continuation, Sun et al. (2020) investigated the multi-scale nexus between oil prices and economic policy uncertainty in the time-frequency domain for G-7 economies. Using the Wavelet coherence methodology, and linear Granger causality test, the results unveil that in the short-term, the association between economic policy uncertainty (EPU) and economic growth is weak but strengthens gradually while approaching to long run. Besides, this interaction is found positive in the long run, while negative in the medium term. The study further reveals that the linear Granger causality from EPU to oil prices exists only for the US. However, in the medium and the long run, all the countries exhibit a strong unidirectional or bidirectional Granger causality. In the case of Columbian economy sectors, Otero (2020) employed the VAR model to examine the oil price shock (via oil demand, oil supply, and aggregate demand) in different sectors. The examined results reveal that only the oil-specific demand and aggregate demand shocks significantly influence the total production in the country. Indirect effects of oil shocks have also been found due to the inter-relationship of different sectors such as the manufacturing industry, water, gas, electricity, etc.

Beside the prior literature of the general period, there is a growing interest of scholars on the consequences of Covid-19 regarding economies, environment, and natural resources commodity prices volatility. The Covid-19 pandemic is declared as the global contagious pandemic since it has disturbed all the economic activities across the globe. Many studies have been done that explicitly provide the influence of oil/natural resources demand and their price volatility in response to the Covid-19 pandemic. For instance, Mzoughi et al. (2020) investigated the impact of the said pandemic on oil prices, economic activities, and carbon dioxide (CO$_2$) emissions while applying the unrestricted VAR model. The study argued that an increase in the Covid-19 infections leads to the decline of crude oil prices. However, this shock is also parallel to the former, by reducing economic activities and CO$_2$ emissions. Besides, the Covid-19 influence is found stronger on the stock market volatility, than that of crude oil price volatility. Similarly, Kartal (2020) studied the influence of the pandemic Covid-19 on the oil prices of Turkey by analyzing the daily data covering July 25, 2019–October 30, 2020. The results obtained via multivariate adaptive regression splines model reveal that the volatility index affects oil prices irrespective of the sample size. Besides, the study argued that the current pandemic influences the importance of efficient variables “including foreign exchange, global volatility, global uncertainty, and credit default swap spread” on the oil prices.

In addition to the prior literature, Yu and Rehman Khan (2021) analyzes the green agricultural product supply chain financing system after the Covid-19 outbreak via evolutionary game model. The results of the study unveil that ESS in the financing game among urban residents and agricultural products suppliers can be enhanced via minimizing the green agricultural product supply chain cost and encouraging its operational ability. Concerning sustainable production and consumption in the Covid-19, Yu et al. (2021) analyzed the disruption in the global supply chain and socioeconomic shocks. The study identified the influence of Covid-19 on various sectors such as economy, environment, society, and energy market, along with the global protective measures. The study provides policy insights based on the empirical investigation. Moreover, Khan et al. (2019) studied green ideology while investigating Asian emerging economies via Fully Modified ordinary least square (FMOLS) and Dynamic ordinary least square (DOLS) approaches. The results of the study illustrates that although customs clearance processes efficiency, logistical services quality, and infrastructure related to trade and transport contribute to economic growth, whereas it also these factors also contributes to environmental and social issues including carbon emissions, climate change, etc.

Moreover, there is extensive literature available including earlier studies of Narayan et al. (2014) and Lee and Chiu (2011), and the recent studies of Kartal (2020) and Balashova and Serletis (2020). These studies have also investigated the oil other natural resources price volatility for different countries and regions and for different time periods and provided empirical evidence of their diverse outcomes.

2. Data and methodology

Based on the earlier literature, the author(s) observed that the contagious disease that disturbs every domestic and international economic activity is the interest and concerned area to work on. China as the leading importer of energy and one of the leading exporters in terms of products and services, it is important to investigate the influence of oil price volatility in the contagious disease period that locked down almost all the countries in the world, which also affect their economic activities and economic growth. Thus, China remained the topic of greater concern where the Covid-19 contagious disease emerges and affects economic activities the most. Therefore, this study adopted only two variables, that is our main variable have been indicated natural resources commodity prices through oil prices, and the GDP at constant 2010 US$. Monthly data have been obtained from the West Texas
Intermediate (WTI, 2021) and the world development indicators (World Bank, 2018). The data cover monthly oil prices and GDP from January 01, 2019, to April 01, 2021.

2.1. Estimation techniques

The estimation has been initiated with the descriptive statistics and normality test. In this concern, we have estimated the mean values, median, maximum, minimum values, and the standard deviation of each observation from the mean value of these two variables. Besides, the skewness and Kurtosis values have also been estimated. However, for the normality of the data, the current study utilized the Jarque and Bera (1987) normality test. This test considers both the skewness and excess Kurtosis combinedly and consider them being zero as revealed the null hypothesis of the normality test. The final form of the under discussion Jarque-Bera test is given as Eq. (1) as following:

\[ JB = \frac{N}{6} \left( S^2 + \frac{1}{4} (K - 3)^2 \right) \]  

(1)

Concerning the estimation techniques, we applied the wavelet power spectrum and the wavelet coherence.

2.2. Wavelet power spectrum and wavelet coherence

Wavelet analysis is a time-scale estimation technique that separates the data into constituent elements of the frequency and analyzes each element in terms of resolution in its scale proportion. The current study explores the time-frequency dependence of economic performance and natural resources commodity price volatility in China, by utilizing the wavelet coherence approach developed firstly by authors Goupillaud et al. (1984). The wavelet approach is considered unique in terms of the combination of both the time domain causality and the frequency domain causality. Hence, this novelty of the wavelet coherence approach allows this study to capture the short-run and long-run causal association between economic performance (GDP) and natural resources commodity price volatility i.e., oil prices (OP). To be more specific, a multi-scale decomposition technique generates a natural framework that displays frequency-dependent for investigating the association between GDP and OP, which is a more representative proxy for natural resource commodity price volatility.

The current study adopts the wavelet (\( \psi \)) based on the wavelet’s Morlet family. The general equation could be extracted as follows:

\[ \psi(t) = i \pi^{-1/4} e^{-\pi a^2} e^{\pi t^2} \]  

(2)

where \( p(t), t = 1, 2, 3 \ldots, T \). Here in the general wavelet equation, two parameters are crucial, i.e., location \( k \) and frequency \( f \). However, the significance of the “K” parameter is to figure out the exact location in time by a variation of the wavelet. On the other hand, the parameter “f” tackles the fluctuations in frequencies. Hence, \( \psi_{k, f} \) is firstly composed by converting the \( \psi \) of the prior Eq. (2). The equation in the transformed form is provided as Eq. (3) below:

\[ \psi_{k, f}(t) = h^{-1/2} \psi \left( (t-k) \frac{f}{f} \right), k,f \in \mathbb{R}, f \neq 0 \]  

(3)

Additionally, earlier mentioned parameter of wavelet i.e., \( k \) and \( f \) allow to construct the continuous wavelet from \( \psi \), which provides the dataset of time-series \( p(t) \) as Eq. (4) below:

\[ W_{\psi}(k, f) = \int_{-\infty}^{\infty} p(t) f^{-1/2} \psi \left( \frac{t-k}{f} \right) dt, \]  

(4)

The priorly generated and mentioned time-series \( p(t) \) along with the corresponding coefficient \( \psi \) is provided as Eq. (5) as follows:

\[ \psi_{p}(k, f) = \frac{1}{\tan} \left( \frac{1}{O \left( |C \left( f^{-1/2} W_{\psi}(k, f) \right) | \right)} \right) \]  

(9)

From the above Eq. (9), the L and O are the lag operators that denote the imaginary and the real part operators, respectively.

Concerning the interpretation, the horizontal line indicates the time dimension, while the vertical line represents the frequency in the wavelet coherence graphical presentation. Furthermore, a lower frequency indicates a higher scale. In sections of time-frequency space where two series are co-variated, the wavelet coherence can be used to identify them. Moreover, the red color implies a strong relationship between series, whilst the blue color denotes a weaker relationship. With no connection between the series, the cold areas away from the significant region reveal time and frequency. The lags and leads phases correlation between the studied variables are depicted in the paradigm of an arrow throughout the wavelet graphical representations. A co-movement among the considered two variables at a specific scale is depicted by the zero phase difference. Furthermore, whenever the arrows are headed towards the right (left), the time series are in phase (anti-phase). When the two series are in phase, it means that the two parameters are heading towards the same path, whereas opposing anti-phase means they are moving in the opposite (reverse) way. Also, an arrowhead going left-up or right-down on a wavelet coherence
schematic graph indicates that the first component is dominating its other counterpart (variable). On the contrary, when the arrowheads left-
down, the second variable(s) take the lead.

Beside the prior methodological representation, there are some ad-
vantages of the wavelet approach which prefer the use of wavelet over
other approaches of causal association among the variables. That is, the
wavelet, specifically the wavelet transform is the Fourier transform’s
improved version. The Fourier transform although has higher power in
analyzing the stationary signals components. However, the wavelet
transforms tackle the non-stationary signal’s components in an empir-
ic investigation (Sifuzzaman et al., 2009). This advantage leads other
econometric estimators due to talking the non-stationarity issues, which
other estimators does not allow for estimation. Besides, one of the dis-
advantages of the wavelet approach is that it only estimates the finite
time series. However, the data consider in this research is finite, there-
fore current study employed the wavelet approach.

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

After the wavelet power spectrum and the wavelet coherence
approach, we further applied the time- and frequency causality tests to
investigate the viable causal association between the variables under
consideration. Unlike Granger (1969) causality test, we applied the Toda
and Yamamoto causality test proposed by Toda and Yamamoto (1995).
This test provides sufficient estimates when the time series variables are
integrated of order zero I (0), one I (1), or two I (2). Additionally, the
Toda and Yamamoto causality test can also be used even if the variables
of the time series are not cointegrated. Also, we may do vector autore-
gressive (VAR) estimates in level using the Toda and Yamamoto cau-
sality test, irrespective as to whether the series’ variables have the same
integration order (d). As a result, there would be no information loss
since the disparity between the time series data is prevented. We used
the techniques of the Toda and Yamamoto (1995) causality test to avoid
the pre-test potential biases while examining the causal relationship
between economic performance and natural resources commodity prices
in China. The typical equation form of the Toda and Yamamoto (1995)
causality test is presented as Eq. (10) below:

\begin{equation}
\begin{bmatrix}
y_{1t} \\
y_{2t}
\end{bmatrix} =
\begin{bmatrix}
\alpha + \beta_1 y_{1t-1} + \ldots + \beta_p y_{1t-p} + \gamma_1 x_2 + \epsilon_t \\
\gamma_2 x_1 + \epsilon_t
\end{bmatrix}
= \begin{bmatrix}
\Phi(L) & \Psi(L) \\
\Psi(L) & \Phi(L)
\end{bmatrix} \begin{bmatrix}
\eta_t \\
\epsilon_t
\end{bmatrix}
\end{equation}

\begin{equation}
\begin{bmatrix}
\epsilon_t \\
\eta_t
\end{bmatrix} = \begin{bmatrix}
\Phi(L) & \Psi(L) \\
\Psi(L) & \Phi(L)
\end{bmatrix} \begin{bmatrix}
\epsilon_t \\
\eta_t
\end{bmatrix}
\end{equation}

where \( y_t \) in the above equation is a vector of \( k \) variables, \( \alpha \) represents
intercept, \( \beta \) is the matrix of parameters, and \( \epsilon_t \) is the error term of
the equation. Besides, the \( t \) in the subscript denotes the time period of
the series. The major distinction seen among the time-domain and
frequency-domain approaches is that the time-domain method reveals to
us when a particular change occurs inside a time series, whereas the
frequency-domain method quantifies the magnitude of that variation.
Granger (1969), Geweke (1982), and Hosoya (1991) proposed testing
techniques and measures for frequency-domain causality tests. Geweke
(1982) constructed a Wald test to break down the spectral density to
perform a causality test at a certain frequency. Breitung and Candelon
(2006) proposed a causality test that incorporates short- and long-run
prediction at a certain pre-specified frequency, based on early work by
Geweke (1982) and Hosoya (1991). This study aims to apply Breitung
and Candelon (2006) test technique to test for the spectral causal asso-
ciation between economic performance and natural resources com-
modity price volatility, which may be stated step by step in the following
Eq. (11):

\begin{equation}
\Theta(L) X_t = \epsilon_t
\end{equation}

where the above equation indicates that the \( \Theta(L) \) is a 2-by-2 lag poly-
nomial of order \( p \), which could be replicated as

\begin{equation}
\Theta(L) = I - \Theta_1 L - \ldots - \Theta_p L^p
\end{equation}

The \( \Theta(L) \) is demonstrated as with the \( I X_t = X_t \). However, it is also
assumed that the vector error to be white noise, that is with \( E(\epsilon_t) = 0 \)
and \( (\epsilon_t \epsilon_t’) = \Sigma \), the term \( \Sigma \) provides symmetric and definite. Besides
Breitung and Candelon (2006) study, we do not include any of the
deterministic terms in Eq. (11) in order to provide the representation
with ease.

As \( \Sigma \) is symmetric and positive definite, thus the Cholesky decom-
position exists there, i.e., \( G’G = \Sigma^{-1} \), where the \( G \) is the assumed that the triangular matrix, the upper triangular matrix is denoted by the \( G \). In
this case, \( E(\eta_t \eta_t’) = I \) whereas the \( \eta_t = G \epsilon_t \). Utilizing the Cholesky
decomposition, the moving averages system representation is as follows
in Eq. (13) and (14), respectively.

\begin{equation}
X_t = \begin{bmatrix}
x_{1t} \\
x_{2t}
\end{bmatrix} = \Phi(L) \eta_t = \begin{bmatrix}
\Phi_1(L) & \Phi_2(L) \\
\Phi_2(L) & \Phi_1(L)
\end{bmatrix} \begin{bmatrix}
\eta_t \\
\epsilon_t
\end{bmatrix}
\end{equation}

\begin{equation}
= \begin{bmatrix}
x_{1t} \\
x_{2t}
\end{bmatrix} = \Psi(L) \eta_t = \begin{bmatrix}
\Psi_1(L) & \Psi_2(L) \\
\Psi_2(L) & \Psi_1(L)
\end{bmatrix} \begin{bmatrix}
\eta_t \\
\epsilon_t
\end{bmatrix}
\end{equation}

where \( \Phi(L) = \Theta(L)^{-1} \) and \( \Psi(L) = \Phi(L) G^{-1} \) in Eq. (13) and (14),
respectively. The spectral density of \( x_{2t} \) can be extracted as Eq. (15) by
utilizing the prementioned representation:

\begin{equation}
f_{x2}(\omega) = \frac{1}{2\pi} \left[ |\Psi_1(e^{-i\omega})|^2 + |\Psi_2(e^{-i\omega})|^2 \right]
\end{equation}

From Eq. (13) and (14), the natural resources commodity price
volatility could be described as the summation of two uncorrelated MA
processes, which is the basic component that also influences economic
performance. However, these components contain the power of pre-
diction for economic performance. This power of prediction for eco-
nomic performance could be identified at every single frequency (\( \omega \)).
Hence, it is worth noticing that the economic performance does not
actually cause the natural resource commodity price volatility at \( \omega \) when
the factor of prediction concerning natural resources commodity price
volatility spectrum at frequency \( \omega \) is zero. This stimulates the causality
analysis as suggested by Geweke (1982) and Hosoya (1991), which
could be presented as Eq. (16) and (17) below:

\begin{equation}
M_{x1 \rightarrow x2}(\omega) = \log \frac{2\pi f_{x2}(\omega)}{|\Psi_1(e^{-i\omega})|^2} = \log \left[ 1 - \frac{|\Psi_2(e^{-i\omega})|^2}{|\Psi_1(e^{-i\omega})|^2} \right]
\end{equation}

The priorly mentioned equations in relevance to the Geweke (1982)
measures are zero if the \( |\Psi_1(e^{-i\omega})|^2 = 0 \). However, because of this fact,
it could be assumed that the natural resources commodity price volatil-
ity does not cause economic performance at frequency \( \omega \).

The preceding equations and conditions have been modified by
Breitung and Candelon (2006) by imposing linear limitations on the
parameters of the first element of the VAR model, as following: the null
hypothesis \( H_0 : M_{x1 \rightarrow x2}(\omega) = 0 \) is equivalent to the linear restrictions, i.e.,

\begin{equation}
H_0 : R(\omega) \beta = 0
\end{equation}

where \( \beta = [\beta_1, \ldots, \beta_p] \) is the coefficients’ vector of economic perfor-

\begin{equation}
R(\omega) = \begin{bmatrix}
\cos(\omega) \cos(2\omega) \ldots \cos(p\omega) \\
\sin(\omega) \sin(2\omega) \ldots \sin(p\omega)
\end{bmatrix}
\end{equation}

The ordinary F-statistics for the prior Eq. (18) is distributed
approximately as \( F(2, T - 2p) \) for \( \omega \in (0, \pi) \). Here, 2 is the restrictions
number and \( T \) indicates the number of the observations applied to
analyze the VAR model of order \( p \).
Although the time dimension is not significant in frequency domain analysis, the frequency method offers distinct benefits over the time-domain approach. That is, in the shorter series investigations, for example, a seasonal pattern may be relevant, and the frequency domain enables such fluctuations to be eliminated. Furthermore, the frequency-domain process allowed us to identify non-linearities and causality cycles, i.e., causation at high and low frequencies. To discover plausible evidence on causality directions between natural resources commodity prices volatility and economic performance in China, we employ the spectral Breitung and Candelon (2006) causality technique.

3. Results and discussion

3.1. Descriptive statistics and the normality results

We begin our analysis by estimating the descriptive statistics of both the variables concerned, i.e., economic performance measured as GDP and the natural resources commodity prices volatility. Concerning the mean and median values of GDP, they are approximately the same and the natural resources commodity prices volatility. Concerning the variables concerned, i.e., economic performance measured as GDP and the natural resources commodity prices volatility, the Jarque and Bera (1987) normality test found 0.68 \( E^{-6} \), which is above the critical values and the wavelet coherence approaches. The wavelet coherence method allows the current study to investigate both the long-run and the short-run association between the natural resource’s commodity prices volatility and economic performance in the pre and post Covid-19 period because this approach unites both the time and frequency domain based causality approaches. Utilizing the wavelet approaches for analysis makes the possibility to assess the degree of co-movement simultaneously at a different frequency over time. Based on these critical factors, the wavelet approach is different and efficient than the other previously developed causality methods. Nonetheless, the current study’s prime motivation is to use the wavelet approach that builds models based on time-frequency. This leads to fill the existing gap in the literature regarding the pre and post Covid-19 conditions of China’s natural resources commodity prices volatility and economic performance by using the wavelet approach.

3.2. Seasonality adjustment

As we considered monthly data for empirical investigation into the nexus of natural resources commodity prices volatility and economic prices, thus the seasonality factor could not be ignored as it also influences our results. In this regard, we seasonally adjusted the data for both the variables under consideration, i.e., GDP and NRCP. The data of the GDP is observed with many fluctuations as shown in Fig. 1. Initially, before the emergence of Covid-19, the economic activities are reported at a peak level. However, after the Covid-19 emergence, the economic activities adversely affected due to the lockdown environment throughout China, that disturbed economic performance and the data provides with the fluctuations. In this regard, the current study employed the Seasonal Trend Decomposition using Loess (STL) method recommended by Cleveland et al. (1990). The said test usually considers the fluctuations in the data due to the seasonality effect along with the trend. Hence, the final graph obtained via the STL decomposition method is smooth enough that tackles the issue of the seasonality factor. Besides, the loess regression curve is a smoothing of given x, which could be estimated for any of the given x values and the independent variable’s scale. Additionally, one important feature of the STL is that it allows to deal with the missing values and detrend the components of seasonality in a straightforward method Cleveland et al. (1990). Hence the final form of the data obtained via the STL decomposition method allows us to further estimates the wavelet spectrum and wavelet coherence.

Concerning the natural resources commodity prices volatility, the same STL decomposition method is used that considers the imbalance fluctuations and the N-shaped trend line and detrends the following to provide the seasonally adjusted time series. Before Covid-19 emergence, the NRCP were noted in the increasing trend as shown in Fig. 2. However, after the emergence of the contagious pandemic, the trend follows a downward direction, which indicates that the NRCP faced great losses. Soon after July 2020, the NRCP in China started an increasing trend. Besides the fluctuations and trends in the data, the STL provided a smooth and seasonally adjusted graph for further estimations.

3.3. The wavelet power spectrum

To identify the behavior of economic performance in the Covid-19 pandemic period and capture the time-frequency dependency of economic performance in China, the current study covering the pre and post Covid-19 pandemic period on the monthly data from January 01, 2019, to April 01, 2021, the present study utilizes the wavelet power spectrum, and the wavelet coherence approaches. The wavelet coherence method allows the current study to investigate both the long-run and the short-run association between the natural resource’s commodity prices volatility and economic performance in the pre and post Covid-19 period because this approach unites both the time and frequency domain based causality approaches. Utilizing the wavelet approaches for analysis makes the possibility to assess the degree of co-movement simultaneously at a different frequency over time. Based on these critical factors, the wavelet approach is different and efficient than the other previously developed causality methods. Nonetheless, the current study’s prime motivation is to use the wavelet approach that builds models based on time-frequency. This leads to fill the existing gap in the literature regarding the pre and post Covid-19 conditions of China’s natural resources commodity prices volatility and economic performance by using the wavelet approach.

Regarding Fig. 3 the black curve communicates to the influence’s cone, which refers to an edge, where the wavelet power discontinued under that edge. Hence, it is then hard to infer. The thick contour line demonstrates the significance level of 5%, obtained via Monte Carlo simulation. The colors mentioned in the power spectrum vary from blue to red, indicating the lowest power to the highest power (Kirikkaleli, 2020). As the recent study is about to cover the pre and post Covid-19 period, thus the only higher wavelet power spectrum for the economic performance is found in the peak of the Covid-19 period. That is, from October 2019 to May 2020, the economic performance is significantly vulnerable at different times and frequencies before and after the Covid-19 peak period.

With reference to Fig. 4, the black curve communicates the influence of the cone where the under edge leads to the discontinuation of the wavelet power. The thick contour line around a specific portion inside the cone reveals the 5% significance level via the Monte Carlo simulation. Hence it is clear from the distinction of the colors that the natural resources commodity prices fluctuate in the Covid-19 peak period, as revealed by the yellowish-orange color. Due to the locked-down
environment in China, economic activities have been reduced to the minimal, which reduced demand for various natural resources including oil between October 2019 and May 2020. However, extensive reduction in the energy demand reduced the NRCP, while on the other hand, the supply remained the same. Which causes a severe reduction in NRCP. Thus, the economic activities and the NRCP is following the same downward path. Hence, it is concluded that the volatility in the economic performance is lower than that of the commodity price volatility.

3.4. Wavelet coherence between variables

In order to capture the causal effect of natural resources commodity price volatility on the economic performance in China over the monthly period data as priorly mentioned, the current study employed the wavelet coherent approach and their findings are provided in Fig. 5. This mathematics’ derived approach unites the information for both the time and frequencies domain causality techniques to achieve the information formerly hidden (Kirikkaleli, 2020). Therefore, the current study undertakes to capture both the long-run and short-run causal association.
between the natural resources’ commodity prices volatility and economic performance in the pre and post Covid-19 era in China. It is worth noticing that if the data under consideration are non-stationary, noisy, structural breaks, and having several volatilities shift, the wavelet coherence method is an efficient approach. Hence, the variables natural resources commodity prices and economic performance are both used at levels in the wavelet models.

Concerning Fig. 5, the color blue (cold) indicates no correlation, while the yellow-orange-red colors reveal higher dependency between the variables under consideration. Regarding the direction of the significant causal association between the variables in the wavelet coherence analysis, the arrows indicate the causality, which is surrounded by the thick black contour. Specifically, there would be a negative correlation between the variables if the arrows are headed towards the left. However, if the arrows are headed towards the right, it indicates a positive correlation among the variables. Additionally, if the arrows are headed to the up, right-up, or left-down, this reveals that the 2nd variable causes the 1st variable, while the 1st variable would cause the 2nd variable if the arrows were headed in the downward, right-down, or left-up directions. Concerning the obtained results in Fig. 5, in October and November 2019, the arrows are pointing left-down, which indicates that the natural resources commodity prices volatility causes economic performance. Specifically, the volatility in the NRCP significantly causes volatility in the economic growth during the Covid-19 period. In addition, the down and right down arrows of the same figure indicate that the volatility in the economic performance causes natural resources commodity prices volatility with the higher frequency. That is, from December 2019 to July 2020, the economic activities were greatly disturbed and affected by the Covid-19 pandemic and the locked-down environment, that extensively reduced the demand for oil in China. Hence, the volatility in NRCP occurs due to economic performance. The findings of the current study showed consistency to the earlier findings of Aloui et al. (2018), Prabheesh and Laila (2020), Baek et al. (2020), and Baek and Young (2020). These findings from the previous studies suggest that the variables’ association evolves through time and frequency. The results unveil strong but heterogenous association from the time domain, while strong lead and lag, and significant wavelet
coherence from the frequency domain among these variables.

3.5. Discussion on the frequency domain causality test

The frequency-domain causality test as proposed by Toda and Yamamoto (1995) provides efficient estimates when the time series variables are integrated of I(0), I(1), or I(2). Additionally, the Toda and Yamamoto causality test can also be used even if the variables of the time series are not cointegrated. Hence, this test is suitable to apply, and the estimated outcomes are shown in Fig. 5. In addition, the BC spectral Granger causality test provides the causal relationship in all the runs, i.e., long-run, medium-run, and the short-run. However, the horizontal red line reveals the relationship among the variables at a 5% significance level. Hence, it could be clearly seen from the under-discussion figure that there is no causal relation between the natural resources’ commodity prices volatility and economic performance in the long-run and the short-run. However, in the medium-run, it is reported that the NRCP volatility significantly affects the economic performance in China at a 5% significance level. The medium-run causal influence is found significant due to the severe impact of Covid-19 at the peak level. However, in the long run, this impact is insignificant due to the fact that the precautionary and alternative measures and policies implemented by the law enforcement institutions. This indicates that the impact of natural resources commodity prices would not affect economic performance in the short run during the Covid-19 pandemic. However, in the medium run, the impact is significant due to the lockdown environment and reduction or postponement of the production and economic activities, which significantly affect economic performance of China. In contrast, the country will rapidly allow for the precautionary measures which would tackle the negative influence of the Covid-19’s affect on the natural resource commodity price volatility and will not adversely affect economic performance.

4. Conclusion and policy implications

Although there is extensive literature available that determines the influence of oil prices on the economic growth for different regions and countries. Also, the literature pointed the influence of Covid-19 on the oil prices for some regions. However, the area of natural resources commodity prices volatility and economic performance in the pre and post Covid-19 era remained unexplored. Hence, the current research aimed to analyze the causal nexus of the natural resource commodity prices volatility and economic performance nexus for China. For this, we have utilized the monthly data covering the period from January 01, 2019, to April 01, 2021. For an empirical investigation, we have used the wavelet power spectrum and the wavelet coherence approaches, which allow both the short and long-run causal association among the study variables. The empirical findings of the wavelet power spectrum illustrate that significant vulnerabilities have been observed in the natural resource commodity prices volatility and economic performance at various frequency levels and time periods. Additionally, the current study underlines that the Covid-19 period strongly affects both the natural resource commodity prices volatility and economic performance. However, the higher volatility has been observed in the natural resource commodity price with the higher frequency, particularly in the peak time of Covid-19, i.e., between December 2019, to July 2020. Besides, the wavelet coherence approach notifies that both the variable significantly causes each other but with different frequencies and in different time periods. Moreover, the current study also utilized the frequency domain causality test, which allows this study to identify the long-run, medium-run, and short-run causal relationship between the study variables. The empirical findings illustrate that the natural resources commodity prices volatility significantly causes economic performance volatility only in the medium-run. Whereas no significant causal relationship has been observed in the short and long run.

Based on the empirical findings, this study recommends practical policy implications, which require immediate attention and implementation in order to maintain the economic performance and control natural resource commodity price volatility. Firstly, the empirical estimates provide that the natural resource commodity price volatility significantly causes significant change in the economic performance, therefore any policy change should consider the economic performance as changes in the policies regarding natural resource commodity prices would significantly affect economic performance of China, specifically after the Covid-19 pandemic. Besides, more dependency on natural resources such as oil consumption although leads to higher economic growth; however, natural disasters such as the Covid-19 pandemic greatly affect the economic performance, thus a proper technologically innovative setup is required in order to manage both the economic performance and natural resource commodity price volatility. Secondly, the empirical estimates also reveal that economic performance significantly causes volatility in the natural resource commodity prices. Therefore, it is critical to make policy measures in a way that prioritize natural resource commodity price in a way to make the volatility lower in order to maintain stable economic growth. Moreover, the precautionary measure must be taken to avoid the emergence of such destructive diseases in the future.

Although this paper empirically investigates the causal association of the natural resource commodity prices volatility and economic performance in both the pre and post Covid-19 pandemic periods. Still, this research study holds limitations by analyzing the only country, i.e., China. However, this research study can be further extended to the empirical investigation of more than one country or regions such as Asian, OECD, or other parts of the world. Besides, current research study uses only the oil prices as the proxy for natural resource commodity prices, whereas other natural resources including crude oil prices, coal prices, mineral prices, among others could be considered by the future researchers. Moreover, the current research study employed the novel Wavelet approaches, which only analyze the vulnerabilities and causal association among the variables. However, other empirical methods are also available and could be employed in the future research that could empirically analyze the specific influence of natural resource commodity price volatility on the economic performance.

CRediT author statement

Qiang Ma: Supervision, Project administration, Funding acquisition. Mei Zhang: Formal Analysis, Conceptualisation. Sher Ali: Conceptualisation, Data Curation, Methodology, Software, Formal Analysis. Dervis Kirikkaleli: Writing final draft, data curation. Zeeshan Khan: Methodology, Software.

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