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China economic performance and natural resources commodity prices volatility: Evidence from China in COVID-19

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ABSTRACT
Since the beginning of the 21st century, the world has faced many challenges, including the 2003 oil price hike, the 2007-08 global financial crisis, among others. While the recent Covid-19 outbreak slowdown economic performance and create uncertainty in natural resources commodity prices, which brought the attention of academic research. Current study examined economic performance and natural resource commodity price volatility in China over the period 1990–2020. Also, this study considers the role of renewable energy investment, renewable electricity output, and green finance in the pre and post Covid-19 pandemic periods. For empirical investigation, this study employed dynamic ordinary least square (DOLS), fully modified ordinary least square (FMOLS), and Canonical Cointegrating Regression (CCR). The outcomes reveal that the first-differenced stationary variables are all cointegrated in the long run. While these estimators confirmed that natural resources commodity price volatility negatively affects economic performance. Besides, the results validate the positive impact of renewable energy investment, renewable electricity output, and green finance on economic performance. The results are found robust and consistent, justified by Robust regression. These findings could have essential economic, natural resources, and energy implications for policymakers, governors, and researchers.

1. Introduction
The emergence of Covid-19 pandemic substantially disturbed most of the countries and regions across the globe, which causes economic slow-down and volatility in natural resource commodity prices, among others. Besides, natural resource commodity such as petroleum markets are currently facing the most volatile times in its history (Bildirici et al., 2020; Mentel et al., 2021). Specifically, the crude oil price volatility is although affected by various macro and microeconomic factors and variables (Xia et al., 2022). Still, the speculative activities and non-economic variables including Gulf war, geopolitical tension, the recent Covid-19 pandemic outbreak, and Russia-Saudi Arabia conflict also contribute to the volatile behavior of natural resources (Bildirici et al., 2020). Currently, the volatility and uncertainty in the natural resource commodity prices due to Covid-19 and the Russia-Saudi Arabia conflict have drastically affected the decision of investors and manufacturers regarding portfolio allocation and industrial production and economy, respectively. The Covid-19 pandemic led global economy into another recession, due to which the oil and other natural resources demand has fall down. In the recent times, this is a burning issue that attracts the attention of scholars and policymakers (Shahzad et al., 2021).

Therefore, this study tends to attract the attentions of academics for innovative policy insights to resolve the issue natural resources commodity price volatility.

Nonetheless, extensive literature has been provided by the scholars that demonstrate the impact of natural resources on economic performance. However, most of the literature is diverted to the economic impact of natural resources. That is, the earlier studies reports that natural resources abundance are hazardous for economic growth and termed as resource curse (Sharma et al., 2021). On the other hand, some scholars opposes that idea and provide evidence of natural resource blessings for economy’s growth (Katoka and Dostal, 2021; Asif et al., 2020). This debate of natural resources curse or blessings have long been discussed. Currently, the burning issue among scholars is whether natural resources commodity prices volatility matters for economic growth or not? From a theoretical perspective, natural resource commodity price volatility has a two-dimensional impact on the economic performance in the country.

Specifically, an increase in the natural resource commodity prices reduces demand for natural resources and postponed economic and production activities in the resource exporting economies (Van Eyden et al., 2019). While the resource importing economies are enjoying the
price hike due to increase in the revenue generation share. On the other hand, if the price of natural resources declines, the resource importing economies start to shrink due to the reduction of resource share to the economy (Fatima et al., 2021; Rafiique et al., 2021). Even so, China is a resource (oil-energy) importing economy, where the economic progress is highly dependent on natural resources and could be greatly influenced by fluctuations on natural resources commodity prices. Therefore, the nexus of these two variables must be addressed in China (Sarwar et al., 2019).

Following the start of reforms in 1978, China has made significant economic development (Guo et al., 2021). Interestingly, the global economy began to shrink after the global financial crisis of 2007–08. Despite this, China’s economy keeps expanding rapidly. The stationary economic growth of China allowed it to deal with both internal and external shocks while still pursuing high-quality development. Even though China has seen significant economic expansion as it remains the world’s top energy importer, energy user, and pollution emitter (Li et al., 2016). China’s coal and oil use account for 70% of total energy consumption (Li and Li, 2020). Hence, China is the world’s leading emitter due to its massive use of natural resources. As a result, the Chinese government took steps to ensure long-term economic growth and environmental sustainability. Scholars and researchers have recommended variety of measures, including resource recycling, cleaner production, an environmental pollution tax, a climate fund, and green finance, among others (Zhou et al., 2020). Furthermore, policies concerning green finance attracted the attention of scholars. The term “green finance” refers to a financial innovation product that aims to create a win-win scenario in terms of both environmental quality improvement and economic performance (Zhou et al., 2020). As a result, green finance may be a critical instrument for reaching a win-win scenario in China. Also, renewable energy investment and renewable electricity output could be affective tools in maintaining higher economic growth and reducing environmental adversity (Al-Darraji and Bakir, 2020; Aydin, 2019). However, these arguments regarding green finance, renewable energy investment, and renewable electricity output are still lacking empirical evidence when it comes to economic performance of China. Hence, current study tends to attract the attention of scholars and policy-makers to this specific issue.

The primary objective of this research study is to analyze the impact of natural resource commodity price volatility on the economic performance of China in Covid-19. As volatility in natural resource prices have been investigated over the time. However, the area remained unexplored in the presence of Covid-19. The second objective of this study is to empirically investigate the impact of renewable energy investment and renewable electricity output on economic performance. The impact of these variables in the environmental perspective has been widely studied. However, in terms of economic impact of renewables, this study considered both of these variables. Furthermore, the green finance is known to have a substantial impact on environmental sustainability. Still, the economic impact of green finance is minimally investigated. Hence, the final objective of current study is to empirically investigate the association between green finance and economic performance of China. To achieve the said objectives, this study uses various econometric approaches as mentioned in Section-3.

This paper contributes to the existing literature in three-fold: firstly, there is limited literature available that empirically investigate the nexus of natural resource commodity price volatility and economic performance. Specifically, the recent studies of Ma et al. (2021), Sun and Wang (2021) analyzed natural resources and economic performance from China and global perspective, respectively. However, these studies only provide the causal nexus of said variables by using wavelet specifications. While current study provides empirical evidence of the specific influence of each explanatory variable on economic performance in China. Secondly, the role of renewable energy investment, renewable electricity, and green finance has been widely studied in the pre-Covid-19 pandemic in relation to economic growth. However, to the best of our knowledge, there is no such study available that empirically investigate these macro-economic variables in the presence of Covid-19 pandemic. Thirdly, the Covid-19 pandemic outbreak is the recent issue that attracts academics attention. Therefore, current study provides empirical evidence of the said issue as contribution to the Covid-19 pandemic related research, which will provide exciting policy implications while considering the Covid-19 pandemic. Moreover, as China is one of the leading economies in the world in terms of trade and GDP, also China remained the first economy to face the adverse effect of Covid-19 pandemic and its following economic down-fall. Therefore, it is necessary to analyze the association between these variables, where the results could be generalized, and policies provision may positively affect other parts of the world. In this regard, it could be stated that this study is comprehensive and would substantially add to the existing literature. We expect that this area of study would attract the researchers and policy-makers attention.

The rest of the paper is organized as follows: Section-2 provides relevant review of literature that cover existing literature for each variable under consideration: Section-3 illustrates the methodology used for empirical investigation of the data: Section-4 presents empirical results and their discussion: Section-5 provides concluding remarks and policy implications.

2. Review of literature

Concerning natural resource commodity price volatility and economic performance, extensive literature has been provided by the scholars and researchers. However, most of the studies proxied natural resources’ prices as crude oil prices. Besides, the literature concerning renewable energy investment, renewable electricity and green finance has also been discussed. After the emergence of Covid-19 pandemic, there is uncertainty in various economic and non-economic factors and indicators. The recent study of Demircan Çakar et al. (2021) demonstrates that both developed and developing countries are affected due to pandemic. However, developing countries are at higher risk due to lower level of health facilities and developed countries faced negative economic growth.

Hayat and Tahir (2021) examined volatility of natural resources and economic performance in case of the resource rich region throughout 1970–2016. Using the autoregressive distributed lags (ARDL) approach, the study found that natural resources are playing positive and significant role in promoting economic growth. However, volatility in the natural resources declines economic performance in UAE, Saudi Arabia, and Oman. This study relates natural resources volatility with the resource curse hypothesis. In the case of ten African mineral dependent economies, Perez and Claveria (2020) investigates data between 2007 and 2017. The study concludes that an average growth in the resource rents does not weakens economic growth, but corruption significantly reduces economic performance of the sample countries. Guan et al. (2021) analyzed the top natural resource dependent economies over the 2000–2020 period and compared them based on the oil dependency and gold dependency prices volatility. Using pooled mean group (PMG) and ARDL estimators, results unveil that volatility in both oil and gold markets could adversely affect economic growth of resource dependent economies. Notably, the authors argued that volatility in the gold market is relatively less impactful than the oil price volatility. Although, volatility in natural resources prices negatively affect economic growth. However, Erdogan et al. (2020a) demonstrates that the military expenditures in Gulf countries cooperation is still increasing despite the fact of oil price volatility.

Various studies proxied natural resource price volatility as the crude oil prices for different countries and regions. In this regard, Yıldırım et al. (2020) analyzed time-varying volatility between the prices of oil and precious metals. The study concludes that the oil market volatility spillover effects the precious metal market. After the emergence of...
Asif et al. (2020) investigated monthly data from January 2005 to January 2019 and employed vector error correction model (VECM). The examined results unveil that the influence of oil prices is positive and statistically significant on economic growth, inflation, and exports of the country. On the other hand, Erdogan et al. (2020b) illustrates that money supply and exchange rates are the primary factors of increased inflation in the European Union member economies during the Covid-19 pandemic. Katoka and Dostal (2021) investigated 45 Sub-Saharan economies throughout 1990–2019 in order to analyze the nexus of international commodity prices, natural resources, and economic performance. The study concludes that natural resources enhance economic growth and contradict resource curse hypothesis. In contrast, Asif et al. (2020) investigated resource curse hypothesis by identifying the dynamic linkage between development of financial sector and natural resources. The study utilized time series data for Pakistan covering 1975–2017 period and employed ARDL-bound testing approach. Empirical findings asserted that natural resources contribute to country’s financial development in the short-run but impede financial development in the long-run. This validates both the resource-blessing and resource-curse hypothesis. In case of the Next-11 countries, Rahim et al. (2021) also validate the negative influence of natural resources on economic growth. In case of Chinese provinces, Wang et al. (2019) used spatial regression over the period from 2005 to 2018 and concludes the existence of natural resources curse in China. Specifically, the authors demonstrate that intra-regional, regional, and total spatial spillover effect of natural resources is negatively associated with economic growth. However, physical capital investment and technical innovation is the driving force of economic growth in Chinese provinces. Besides, Zameer et al. (2020a) argued that efficiency in resources utilization is greater in the eastern region relative to other regions. However, the eastern region is reported lower in financial development compared to other regions. Using the structural equation modelling specifications, Yasmeen et al. (2021) discovered natural resources curse in case of Pakistan during the period from 1990 to 2018. Also, the study unveils that non-renewable energy promote economic growth at a higher phase than renewable energy. On the other hand, financial openness encourages economic performance of the country but does not transform natural resources curse into benefits. The inefficient use of natural resources such as oil, and particularly in the production activities are the leading factors of environmental pollution, reduces governmental control, and strengthens government regulations. The authors also argued that increase in the renewable energy investment significantly promote economic growth in the region. However, investment in renewable energy could only be increased if it contributes to economic growth. Concerning, number of studies are available that empirically investigate the impact of renewable energy on economic performance. Specifically, Fan and Hao (2020) investigated the linkage between renewable energy consumption and economic growth in 31 Chinese provinces between 2000 and 2015. Employing VECM and Granger causality approaches, the study found that renewable energy and economic growth along with the foreign direct investments are in the long-run equilibrium relationship. The study of Khan et al. (2020) provides evidence that renewable energy consumption significantly improves both environmental and economic conditions in the ASEAN economies. In case of Azerbaijan, Mukhtarov et al. (2020) investigated the impact of renewable energy consumption and investment is extensive as some other studies including Alam and Murad (2020) for OECD, Rahman and Velayutham (2020) for South Asian economies, Arain et al. (2020) for China analyzed various time periods and revealed that there are multiple factors that influences renewable energy use, which contribute to economic growth. Beside natural resources and renewable energy, renewable electricit could also influence economic performance. In this regard, one of the recent studies of Aydin (2019) investigated the nexus of both renewable and non-renewable electricity consumption and economic performance in the 26 OECD economies. Using the data of 1980–2015 period, the study concludes that there is a bidirectional causal association between renewable energy, non-renewable energy and economic growth in the region. Al-mulali et al. (2014) analyzed electricity consumption and economic growth nexus in the Latin America throughout 1980–2010. The DOLS estimator has been employed and the empirical findings revealed that renewable electricity consumption is playing more significant role in economic growth promotion than the non-renewable energy consumption. On the other hand, there are studies that confirmed the positive influence of renewable electricity on the environment quality of 5 European Union countries (Balsalobre-Lorente et al., 2018) and Algeria (Belaid and Youssef, 2017). Hence, the studies confirmed the positive impact of renewable energy not only on the economic growth, but also on the environmental sustainability for various regions and countries. In addition to the prior literature, scholars also provide literature on the role of green finance in economic performance but comparatively not extensive. However, the recent study of Zhou et al. (2020) investigated 30 Chinese provinces between the 2010–2017 period. The examined results unveil that green finance development play a significant role in the development of an economy. Also, the authors argued that development of green finance leads to win-win situation of both economy and environment. Still, the positive influence of green finance on environmental sustainability depends upon economic condition of the region or country. In continuation, Ren et al. (2020) also investigated China throughout the period of 2000–2018. The findings of the study asserted that green finance impede carbon dioxide level in the environment and contribute to economic growth of the country. Moreover, the empirical investigation of Cui et al. (2020) unveils that green financial development positively affect economic sustainability and contribute to cleaner production. Furthermore, green finance also enhances compensation for consumers’ pollution, reduces governmental cost of supervision, and strengthens government regulations. Although, there are numerous studies that covered each variable this study considered. However, there is no such study found in the available literature that empirically investigated natural resource commodity price and economic performance specifically in the Covid-19. Also, these
studies ignored the role of renewable energy investment, renewable electricity, and green finance. Therefore, to fill this gap, current study contributes to the existing literature by investigating all the mentioned variables in case of China.

3. Model specification and methodology

3.1. Theoretical framework and model specification

Since the Covid-19 outbreak is first diagnosed in Wuhan city of China, it has spread over 190 countries across the globe in 2020. This continual and rapid growth in Covid-19 cases causes economic situation highly fluid. Uncertainty over the depth and length of the health-care crisis’ economic consequences is feeding risk and volatility perceptions in financial markets and business decision-making. Furthermore, market volatility is exacerbated by concerns about this contagious disease and the feasibility of state interventions aimed at controlling its spread (Mentel et al., 2021). Corporations are deferring investment strategies, firing off previously furloughed staff, and in some cases declaring bankruptcy. A record decrease in the price of crude oil, which reflects the worldwide reduction in economic activity and chances for dissemination while also contributing to the global economy’s downturn, through numerous channels, has added to the economic crisis. The major reason of uncertainty in natural resources prices is Covid-19 pandemic (Bildirici et al., 2020; Sharif et al., 2020). Thus, uncertainty in natural resources commodity prices tends investors to postponed investments in various projects, which are the factors of economic performance and growth. Moreover, the recent conflict regarding Saudi Arabia and Russia for oil trade also trigger uncertainty in natural resources commodity market (Bildirici et al., 2020). These countries are intended to capture energy market, which lead them to supply at lower prices, while demand has been dramatically fallen due to the lock-down environment. Since economies are highly dependent on natural resources for energy motives, which also harms environment. Therefore China, among others, are paying more attention towards innovative policies that could have two major contributions, i.e., economic and environmental. Specifically, the focus on green finance, investment in renewable energy, and renewable electricity could lead to achieve the target of higher economic growth and carbon neutrality by 2050. Green finance enhances the product innovation which are aimed to improve environmental quality and promote economic growth by encouraging environmentally friendly technologies and products (Ren et al., 2020; Cui et al., 2020; Zhou et al., 2020). Moreover, investment in renewable energy sources could have a long term advantageous affect on economic growth by the channel of improved production structure and industrial expansion (Al-Darraji and Bakir, 2020; Aydin, 2019; Al-mulali et al., 2014).

Based on the theoretical notion and literature provided in Section-2, this study used a total of five variables, including economic performance proxied by GDP and measured in the constant US$ 2010, total natural resource rent for natural resource commodity price volatility (NRV), Investment in renewable energy (IRE), Renewable electricity output (REL), and Green finance (GF). This study motivated by the study of Ma et al. (2021), where the research is more oriented to natural resources commodity price volatility and economic performance nexus. As China remains the top of the list to face the sever impact of Covid-19 pandemic impact on economy. Also, the recent trend in China demonstrates policies concerning environmental sustainability led this study to analyze the influence of NRV on economic performance of China in the pre and post-covid-19 pandemic periods. Also, the role of IRE, REL and GF has been considered to analyze whether these environmental factors do really impact economic performance of China in the Covid-19 pandemic. In this regard, time series data has been obtained from various sources covering the period from 1990 to 2020 for China. The reason for selecting extended dataset is to cover and investigate the said issue more comprehensively. The variables, description, and specific data source has been provided in Table-1.

Based on the objectives of study and variables under consideration, this study constructed the following general model:

3.1.1. Model

\[ \text{GDP}_t = f(\text{NRV}_t, \text{IRE}_t, \text{REL}_t, \text{GF}_t) \]

where the above model shows that NRV, IRE, REL, and GF is the function of GDP, which represents economic performance of China over the time. However, the priorly mentioned model could be transformed into regression form as provided in Eq. (1) below:

\[ \text{GDP}_t = \beta_0 + \beta_1 \text{NRV}_t + \beta_2 \text{IRE}_t + \beta_3 \text{REL}_t + \beta_4 \text{GF}_t + \epsilon_t \]

where in the above Eq. (1), GDP represents economic performance, NRV indicates natural resource commodity price volatility, IRE denotes investment in renewable energy, REL represents renewable electricity output, and GF denotes green finance of China. Moreover, \( \beta_0 \) represents intercept and the rest of the beta’s denoted slope of NRV, TRE, REL, and GF, respectively. Besides, \( t \) in the subscript denotes the time-series of each variable.

3.2. Estimation strategy

After construction of the model based on the variables under consideration, an efficient econometric approach is required for an empirical examination. In this regard, current study utilized various time-series approaches which are based on the properties of data. Specifically, the property of stationarity is required for empirical investigation of time series. Therefore, this study used Augmented Dickey-Fuller (ADF) test, which is efficient due to tackling the serial correlation issue and is more powerful than simple Dickey-Fuller unit root test. The results demonstrates that all the variables are stationary at first difference, which allows us to identify cointegration between the study variables. Therefore, we utilized the Bayer-Hanck combined cointegration test which enhances cointegration analysis power and tackles uncertain or ambiguous estimates (Shahbaz et al., 2018). After existence of the long-run association between the study variables, it is important to use efficient long-run estimator. In this sense, current study used dynamic ordinary least square (DOLS), fully modified ordinary least square (FMOLS) and Canonical Cointegrating Regression (CCR). These approaches hold higher efficiency in tackling the issue of serial correlation.

| Variable | Description | Data Source |
|----------|-------------|-------------|
| GDP | Gross domestic product is the total of gross value contributed by all resident producers in the economy, plus any product taxes, subtracting any subsidies not included in the product value. | World Bank (2021) |
| NRV | In the total natural resource rent (% GD) the oil rents, natural gas rents, coal rents (hard and soft), mineral rents, and forest rents are all added together. | World Bank (2021) |
| IRE | Investment in renewable energy is a form of environmentally/socially responsible investment that focuses on renewable energy resources such as wind, solar, biofuels, hydropower, tidal power, and the technologies and systems associated with these sources. | World Bank (2021) |
| REL | Renewable electricity output is the percentage of total electricity generated by all types of power plants that is generated by renewable power plants. | World Bank (2021) |
| GF | Green finance refers to investment in industrial sector to curb pollution. | China Bureau of Statistics (2021)* |

* Visit China Bureau of Statistics, available at: http://www.stats.gov.cn/english/.
and endogeneity. Besides, CCR provides efficient long-run estimates due to its essential role in fixing the linear regression part (Park et al., 2010). After, we use Robust regression for validation of empirical findings of the said approaches.

### 3.2.1. Descriptive statistics and normality check

Before moving to empirical analysis of the data, current study firstly estimated the descriptive statistics in order to summarize the data of variables under consideration. The descriptive statistics includes mean, median and the range (i.e., minimum, and maximum values) of the data. Besides, this study also identified the standard deviation of the variables. The descriptive statistics includes mean, estimated the descriptive statistics in order to summarize the data of normality of the data. In this regard, we employed the normality test median and the range (i.e., minimum, and maximum values) of the data.

After the descriptive statistics, current study also tested the normality of the data. In this regard, we employed the normality test proposed by Jarque and Bera (1987). This test considers both the skewness and excess kurtosis in a combined manner in order to specify the behavior of each selected variable. Concerning the Jarque and Bera (1987) normality test, the null hypothesis assumes that the data for each variable under-taken is normally distributed. The normal distribution of the Jarque-Bera test indicates that both the skewness and excess Kurtosis are being zero. Generally, the Jarque and Bera (1987) normality test could be presented in the final form as Eq. (2) below:

\[
J_B = N \frac{S^2}{K - 3} + \frac{1}{4} (K - 3) = 0
\]

### 3.2.2. Unit root testing

After calculating the descriptive statistics and checking for the normality of each variables’ data, this study moves to test for the stationarity or presence of unit root in the time-series variables. In this regard, we employed Augmented Dickey-Fuller (ADF) unit root test. Concerning the ADF unit root test, which is proposed by Dickey and Fuller (1979) is efficient due to tackling the serial correlation issue. Also, this test is more powerful than the simple Dickey-Fuller unit root test because it can control more complex models. The general form of the ADF unit root test could be provided as following in Eq. (3):

\[
y_t = \gamma + \phi t + \mu y_{t-1} + \epsilon_t
\]

where the above Eq. (3) could be analyzed by the ordinary least square (OLS) estimator, provided as following:

\[
\Delta y_t = (\mu - 1)y_{t-1} + \gamma + \phi t + \epsilon_t
\]

Beside the general equation form, it is noteworthy that the adopted ADF unit root test has two versions, that is with the intercept, and with the trend. Moreover, the ADF unit root test assumes that the unit root is present as a null hypothesis.

### 3.2.3. Bayer-Hanck combined cointegration test

After testing for the unit root or stationarity of the data, this study further examined the cointegration association between the considered variables. In order to analyze the cointegration association between these variables, we employed the Bayer-Hanck combined cointegration test that considers Engle and Granger (1987), Johansen (1991), Banerjee et al. (1998), and Peter Boswijk (1994) cointegration tests combinedly. However, if these tests are employed separately, the cointegration test could provide uncertain results due to their explanatory power properties (Shahbaz et al., 2018). Therefore, to enhance the power of cointegration analysis and overcome uncertain or ambiguous estimates, we employed the combined cointegration test approach proposed by Bayer and Hanck (2009). This test considers all the prementioned tests of cointegration in a combined approach and provides conclusive and reliable results through Fisher F-statistics (Shahbaz et al., 2018). Moreover, this test requires unique order of integration, i.e., I(1). The said test assumes no cointegration among the variables under consideration as a null hypothesis. However, this could be rejected is the estimated values are significant at any level of significance, i.e., 10%, 5% and 1%. Generally, the Bayer-Hanck cointegration Fisher’s formula could be presented as following:

\[
EG - J = -2[\ln(P_{EG}) + \ln(P_j)]
\]

\[
EG - J - Ba - Bo = -2[\ln(P_{EG}) + \ln(P_j) + \ln(P_{bo}) + \ln(P_{bo})]
\]

In the above mentioned Eq. (6), the P_{EG}, P_j, P_{bo} and P_{bo} are the probability values for Engle and Granger (1987), Johansen (1991), Banerjee et al. (1998), and Peter Boswijk (1994) cointegration tests, respectively. However, these formulations of Fisher’s statistics indicates whether the cointegration exists between the variables under consideration.

### 3.2.4. Long-run estimations

After employing the Bayer and Hanck (2009) combined cointegration test, the long-run association between the variables under consideration has been confirmed. This allows current study to examine the influence of each independent variable i.e., NRV, IRE, REL, and GF on the economic performance of China. In this regard, we need to utilize efficient and unbiased estimator. Thus, following Khan et al. (2019), we used three long-run estimating approaches. Such approaches include dynamic ordinary least square (DOLS) provided by Pedroni (2000), fully modified ordinary least square (FMOLS) and the Canonical Cointegrating Regression (CCR) proposed by Park (1992). The earlier mentioned two methods are utilizing different approaches, i.e., parametric (DOLS) and non-parametric (FMOLS) approaches. Furthermore, these are reliable measures of the long-run estimation due to higher efficiency in tackling both endogeneity and serial correlation issues. Besides, the DOLS estimator is also efficient for the time series estimation as this also tackles the issue of non-stationarity. Moving forward, both FMOLS and DOLS could be presented in the equation form as below in Eq. (7) and Eq. (8), respectively.

\[
\phi = [q] = \begin{bmatrix} \sum_{t=2}^{T} Z_{it} \end{bmatrix}^{-1} \begin{bmatrix} \sum_{t=2}^{T} Z_{it} y_{it} - T \theta_{it} \end{bmatrix}
\]

where Z_{it} = (X_{it}, D_{it}). On the other hand, the long-run covariance matrix is playing crucial role in analyzing the FMOLS estimator.

\[
y_{it} = X_{it} \beta + D_{it} \gamma_{it} + \sum_{t=1}^{T} \Delta X_{it} \sigma + v_{it}
\]

The DOLS estimating approach includes the augmentation of cointegration regression while considering both the lead and lags \Delta X_i because of the orthogonal error term cointegration equation. The said estimator assumes that adding r leads and q lags of the differences regressors, the long-run correlation could be observed among e_{u2} and e_{u2}. In addition, the CCR estimating approach as mentioned earlier, is purely a regression based approach. Where this approach is efficient and playing essential role on fixing the linear regression part (Park et al., 2010). Hence, the identification of exact leads and lags orders are the critical issues for the said approach. Generally, the CCR estimators could be presented in the equation form as Eq. (9) below:

\[
y^*_{it} = \beta_{pq} z_{pq} + \eta_{pq}
\]

where the above Eq. (9) reveals that both y^*_{it} and z_{pq} are the stationary transformation of y_{it} and z_{pq}, respectively.

Besides the priorly mentioned estimating approaches, we also use the Robust regression approach in order to confirm and validate the findings of these three long-run estimators. Robust regression is a type of regression analysis used in robust statistics to avoid several of the constraints of standard parametric and non-parametric approaches. The goal of regression analysis is to figure out how one or more independent variables relate to a predictor variable. Ordinary least squares (OLS), for
example, has favorable features when its basic assumptions are valid, but can produce biased estimates if such assumptions are not true; hence, the OLS is considered to be not resilient to assumptions violations. Robust regression techniques are meant to be unaffected by the underlying data-generation process’s violation of assumptions. Besides, when data is compromised with outliers or influential observations, robust regression is an alternative to OLS regression, and it may also be used to discover influencing observations. Moreover, robust regression is an iterative technique for detecting outliers and reducing their influence on parameter estimations. A specific curve called an influence function controls the amount of weighting provided to each observation in robust regression.

4. Results and discussion

4.1. Results

We begin our discussion section by providing the descriptive statistics and normality test outcomes for the variables under consideration. The descriptive statistics and normality test statistics are provided in the Table-2. Concerning mean and median values of the GDP, both of these values are accounted for 12.55055 and 12.55171, respectively, which are approximately the same. However, the minimum and maximum values 11.91796 and 13.07133, respectively, which indicates that the value of GDP changes over the time. Thus, the standard deviation value is accounted for 0.360520 variation from the mean value of GDP. Furthermore, the skewness provides the value of -0.134462, which is approximately similar to the tabulated value of skewness, i.e., 1. While Kurtosis is accounted for 1.752222, which is not similar to its tabulated value. Hence, the insignificant p-value leads to accept the null hypothesis of data being normal.

Kurtosis value is reported less than its tabulated value. Still, the Jarque-Bera normality test provides the value of 2.104473, which is approximately similar to the tabulated value of skewness, i.e., 1. While Kurtosis is accounted for 1.752222 variation from the mean value of GDP. Furthermore, the skewness provides the value of -0.134462, which is approximately similar to the tabulated value of skewness, i.e., 1. While Kurtosis is accounted for 1.752222, which is not similar to its tabulated value of three, respectively. Additionally, the Jarque and Bera (1987) normality test provides statistics for the GDP, accounted for 2.104473, with the probability value of 0.349156. This leads to accept the null hypothesis of data being normal and conclude that the GDP variable is normally distributed across the time-series. With reference to NRV, the mean and median values are approximately the same, that is 0.507261 and 0.505178 percent of GDP, respectively. However, there is a greater difference noted between the minimum (0.020060) and maximum (0.987010) values. Therefore, a standard deviation of 0.272753 is reported from the mean value of NRV. The Jarque-Bera test statistics has been estimated as 1.535553, with the probability value of 0.464044. Thus, the insignificant p-value leads to accept the null hypothesis of data being normally distributed.

With reference to the descriptive statistics of IRE, the mean and median values are accounted for 10.36271 and 10.05077. While the minimum and maximum values are provided as 11.91796 and 13.07133, respectively. The difference between minimum and maximum values of IRE indicates the presence of higher standard deviation from the mean value, accounted for 0.410027. Additionally, the skewness and Kurtosis are not approximately the same as of their tabulated values. However, the Jarque-Bera normality test provide insignificant statistics, which leads to the acceptance of null hypothesis that the data is normally distributed. Concerning REL, the mean value is accounted for 1.271914 and the median value is accounted for 1.257401 percent of the total electricity. As the range values have a very small difference, thus the standard deviation is reported the smallest of all variables, i.e., 0.058151 variation from the REL mean value. Beside the descriptive statistics, the Jarque-Bera normality test provide insignificant estimates, which leads to accept the null hypothesis. Hence, it is concluded that the variable REL is normally distributed. Lastly, the mean and median values of GF is noted approximately the same, while a difference has been observed in the minimum and maximum values. That is, investment in the GF ranges from the minimum of 6.086524 to the maximum of 6.998979 values. Besides, the skewness value is observed approximately the same as its tabulated value. However, the Kurtosis value is reported less than its tabulated value. Still, the Jarque-Bera test provide estimates in the favor to accept the null hypothesis. Hence, along with the GF, it is concluded that all the variables’ data is normally distributed.

Table 3

| Variables | Intercept and Trend |
|-----------|---------------------|
| ADF       | I(0)                |
| GDP       | -1.628476          |
| NRV       | -1.612580          |
| IRE       | -1.678417          |
| REL       | -2.400861          |
| GF        | -2.349696          |

Note: Significance is indicated by 10, 5, and 1% though *, **, and ***.

4.2. Results

As discussed earlier, this test considers Engle and Granger (1987) (EG), Johansen (1991) (J), Banerjee et al. (1998) (Ba), and Peter Boswijk (1994) (Bo) cointegration tests combinedly. Additionally, the said test also provides Engle and Granger (1987) and Johansen (1991) combined estimates. The estimated results are provided in the Table-4. The examined results unveil EG-J and EG-J-Ba-Bo findings highly statistically significant at 1%, 5% and 10% levels. Besides, the results also provide significant results for Engle and Granger (1987), Johansen (1991), and Peter Boswijk (1994). This leads to the rejection of null hypothesis of no cointegration among the variables under consideration. Hence, it is concluded that GDP, NRV, IRE, REL, and GF are in the long-run relationship. Thus, any policy regarding NRV, IRE, REL, and GF could significantly affect economic performance in China.

Once the cointegration relationship between the variables is examined, this allows us to investigate the long-run specific influence of each variable on Chinese economic performance. In this regard, we utilized three estimating approaches, i.e., FMOLS, DOLS and CCR, the estimated outcomes of which are provided in the Table-5. Here, the specific impact of each variable is provided. That is, the influence of NRV is reported as negative, while IRE, REL and GF are noted to have a positive influence.
Concerning the positive and significant impact of GF on Chinese economic performance, the study also confirmed the positive impact of GF in growth and development of different countries and regions. Such studies include Zhou et al. (2020), which demonstrates that development of green finance leads to win-win situation in both the environmental sustainability and economic growth achievement in China. Moreover, Ren et al. (2020) and Cui et al. (2020) also confirmed the positive impact of GF in growth and development of economy. The earlier also mentioned that green finance also enhances supervision, and strengthen government regulations.

Moreover, as the empirical findings of current study demonstrates positive impact of renewable electricity on economic performance. There are many studies available in the literature that revealed consistent results to this study’s findings including Aydin (2019) and Al-mulali et al. (2014), which reveals that renewable electricity significantly contributes to the economic growth of 26 OECD and Latin America. These studies also confirmed that the influence is even greater and highly significant than the non-renewable electricity consumption. Concerning the positive and significant impact of GF on Chinese economic performance, there are number of studies that provide evidence of the similar positive impact on economic performance and growth in different countries and regions. Such studies include Zhou et al. (2020), which demonstrates that development of green finance leads to win-win situation in both the environmental sustainability and economic growth achievement in China. Moreover, Ren et al. (2020) and Cui et al. (2020) also confirmed the positive impact of GF in growth and development of economy. The earlier also mentioned that green finance also enhances compensation for consumers’ pollution, reduces governmental cost of supervision, and strengthens government regulations.

Beside FMOLS, the findings of DOLS and CCR also exhibit similar impact on the Chinese economic performance. Although there is a slight difference in the magnitude of each exogenous variable on economic performance. Still, the overall impact remained the same. Moreover, the findings of DOLS and CCR are found highly statistically significant, which support the FMOLS findings. That is, the NRV is found to have a negative impact on economic performance, while IRE, REL and GF exhibit positive impact on the Chinese economies throughout the selected time period.

After identifying the specific impact of each exogenous variable on Chinese economic performance, this study further checked for the robustness or validity of the empirical outcomes obtained by employing FMOLS, DOLS and CCR. In this regard, we utilized the Robust regression estimator, and the outputs are provided in Table-6. The estimated results reveal similar findings as discussed earlier. Still, the magnitude is reported different. Specifically, a one percent increase in the volatility of natural resources declines economic performance of China by 0.2608%. While a one percent increase in IRE, REL, and GF enhances economic performance by 0.6168, 0.5762 and 0.5637%, respectively. The estimated results are found highly statistically significant at all levels of significance, i.e., 1%, 5% and 10% level. Hence, the findings of the Robust regression validate the empirical results obtained via FMOLS, DOLS, and CCR. Also, the obtained results showed consistency to the previous empirical studies for various regions along with China. Besides, the standard error value(s) for each variable is noted as smaller, which further support the results of earlier estimators.

4.2. Discussion

Volatility in natural resources commodity prices is of great concern as the empirical findings suggest. Specifically, the natural resources commodity prices volatility is found to offset economic performance of China. The reason for this negative association between the two is that when the prices of these resources fluctuate, it creates uncertainty in investors. Due to this uncertainty, investors postponed their investment in natural resources such as oil, coal, natural gas, etc. which restrict industries from further production. Due to declination in production and other economic activities, income circulation decreases, which harms economic growth by increasing the level of unemployment and supply reduction of goods and services. The empirical findings of current study are consistent to the existing studies of Ma et al. (2021), Sun and Wang (2021), Hayat and Tahir (2021). Where these studies mentioned that volatility in natural resources and particularly in the Covid-19 pandemic is detrimental for economic growth (Sharif et al., 2020). On the other hand, current findings are contrary to the empirical findings of Asif et al. (2020), which demonstrates that volatility in natural resources is helpful in developing financial system – leads to economic stability.

In addition, renewable energy investment and renewable electricity promotes economic growth as demonstrated by empirical findings. Specifically, an increase in renewable energy investment provide opportunity to industrial sector’s transmission from non-renewable energy sources. This transmission although required high cost at the initial stage. However, in the long-run, such transformation is beneficial due to the fact of lower dependency on traditional energy resources, and natural resources commodity prices volatility. Which leads to the expansion

Table 5
Empirical results.

| Variable(s) | Coefficients | Std. Error |
|-------------|--------------|------------|
| NRV         | -0.3324***   | 0.0560     |
| IRE         | 0.6634***    | 0.1069     |
| REL         | 0.5875***    | 0.1224     |
| GF          | 0.5293***    | 0.0999     |
| Constant    | 5.6897***    | 0.3710     |

Note: Significance is indicated by 10, 5, and 1% though *, **, and ***.

Table 6
Robust regression.

| Variable(s) | Coefficients | Std. Error | Prob |
|-------------|--------------|------------|------|
| NRV         | -0.2608***   | 0.0631     | 0.0000 |
| IRE         | 0.6168***    | 0.1220     | 0.0000 |
| REL         | 0.5762***    | 0.1273     | 0.0000 |
| GF          | 0.5637***    | 0.1188     | 0.0000 |
| Constant    | 5.3814***    | 0.4425     | 0.0000 |

Note: Significance is indicated by 10, 5, and 1% though *, **, and ***.
and rapid production of industry and enhances economic performance of China. There are other existing studies that also empirically investigates renewable energy investment and economic growth nexus while providing consistent results to current results (Fan and Hao, 2020; Saidi and Omri, 2020; Al-Darraji and Bakir, 2020; Al-mulali et al., 2014). Moreover, enhancement in green finance further stimulates investment in renewable energy production. Besides, green finance increases compensation for pollution of consumers, decreases supervision cost of the government and intensify states’ regulations (Cui et al., 2020). Thus, not only from economic perspective, but green finance could also lead to environmental protection by promoting environmentally friendly production. Thus, current findings are in line with the earlier findings of (Zhou et al., 2020; Ren et al., 2020; Cui et al., 2020), which validates the positive role of green finance in a country’s economic growth and development.

5. Conclusion and policy implications

5.1. Conclusion

The most contagious event the world faced in 21st century is the outbreak of Covid-19, which not only adversely affect human health but also hinders global economic growth and development. The rise in the Covid-19 cases and deaths, significantly increase fear across the world, which postponed multiple economic and production activities. This postponement in economic and production activities reduces demand for most of the natural resources, which causes uncertainty and volatility in the natural resource commodity prices. Besides, there are multiple factors that determines economic growth and economic performance of the country. However, natural resources are playing substantial role in this regard due to fulfilment of the energy requirement for industrial production and other economic activities such as transport. Moreover, China remained the first country that faced the Covid-19 pandemic outbreak, which significantly affect their economic conditions. In this regard, current research study investigates volatility in the natural resource commodity prices and economic performance in China, particularly in both the pre- and post-Covid-19 pandemic periods. Also, this study analyzes the role of investment in renewable energy, renewable electricity output, and green finance in economic performance. Time series data has been utilized that covers the period from 1990 to 2020. While empirical estimates have been obtained by employing various econometric approaches.

The estimating strategy considers the ADF unit root test, which demonstrates that the data for all the study variables is stationary at (1). Also, all the variables are found cointegrated in the long-run, which demonstrates that change in any of the study variable will cause significant changes in other variable(s). Afterwards, current study used fully modified ordinary least square, dynamic ordinary least square, and Canonical Cointegrating Regression to test for the specific influence of explanatory variables on economic performance. The empirical findings obtained reveals that natural resources commodity price volatility have a significant negative affect on economic performance of China. This illustrates that as volatility in natural resource prices increase, investment and production activities is postponed due to uncertainty in the market. On the other hand, investment in renewable energy, renewable electricity output, and green finance are found the significant contributor of economic performance before and during the Covid-19 pandemic. The obtained results are robust and consistent to the literature, as confirmed by Robust regression.

5.2. Policy implications

Based on the empirical findings, this study provides some practical policy implication for the immediate action of policy-makers and governors. Firstly, the findings suggest that volatility significantly impede economic performance in China. Therefore, it is suggested that policy should be design that regulates the natural resources prices to avoid volatility. Specifically, price ceiling or price fixing policies could be effective in tackling volatility in natural resources commodity prices. Also, it is suggested that policies could be design that consider transition towards renewable energy sources in order to reduce the negative impact of natural resource commodity prices on economic performance and reduce natural resources dependency. Secondly, the empirical findings suggests that renewable energy electricity should be considered as a primary energy source for industrial sector, which not only contribute to economic growth, but also leads to environmental sustainability. Thirdly, policies must consider increase in renewable energy investment to eradicate dependency on non-renewable energy and further fuel economic growth in the country. This policy will also tackle the issue of volatility in natural resources commodity prices as most of the energy requirement is fulfilled via natural resources (oil, coal, etc.). Lastly, empirical findings suggest that policies concerning macro-economic and environmental quality should consider green finance development in the country. This will lead China to a win-win situation in both the economic development and achieving sustainable environment in China. As China is the leading energy importer and carbon emitter in the world. Therefore, enhancing investment in renewable energy and green finance could lead increase renewable energy production, which has a bipolar advantage: (i) the declination of energy imports and, (ii) decrease in natural resources dependency, which will ultimately lead to reduce volatility in natural resources.

CRediT authorship contribution statement

Ming Deng: Supervision, Project administration, Funding acquisition, Formal analysis, Conceptualization, Conceptualization, Data curation, Methodology, Software, Formal analysis.

Data availability

The data that has been used is confidential.

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