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Analyzing the nexus of COVID-19 and natural resources and commodities: Evidence from time-varying causality

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ABSTRACT

Even though a few studies have focused on natural resources and commodity sectors by considering the pandemic, they have only compared their status in pre-COVID19 to post-COVID19. None of the studies has directly examined the causal relationship between the pandemic, and natural resource index and the primary commodity-related sector indices. This study fills the gap of exploring the dynamic association between them by analyzing the causal relationship between the COVID19, and natural resources index and the primary commodity-related sectors (i.e., agribusiness, energy, and metals & mining) by applying a novel time-varying causality test on daily data from January 23, 2020, to November 12, 2021. The empirical results support the presence of time-varying causality from COVID19 to natural resources, agribusiness, energy and metals & mining. The results obtained from the rolling window algorithm support causal linkages between the variables however at several points it fails to capture the dynamics of linkages between the variables which is captured by the recursive window algorithm. The outcome is robust when the pandemic is proxied by either number of cases or deaths. Similarly, the findings obtained from heteroskedastic-robust specification also validate our findings. Several policy implications are further discussed in the study.

1. Introduction

The COVID19 pandemic has overwhelmed all economies around the globe after the crisis was declared a global pandemic by World Health Organization in March 2020 (Atri et al., 2021). The pandemic resulted in a grave economic recession owing to worldwide lockdowns and the shutting down of many service sectors such as restaurants, hotels, tourism, and social distancing. As the uncertainty associated with the pandemic affected all spheres of life, natural resources are not an exception to this effect. The pandemic negatively influenced the demand for natural resources (Hordofa et al., 2022), created fluctuations in commodity prices due to measures taken to flatten the pandemic curve (Gray, 2020), and was the main reason behind fluctuations in the stock market (Gao et al., 2021; Li et al., 2021). Particularly, the increased pandemic uncertainty enhanced volatility in the gold market while declining the volatility in the commodity market over the crisis period (Bakas and Triantafyllou, 2020). On one hand, these uncertain conditions and nationwide closures decreased the demand for oil causing a decline in prices. On the other hand, demand for precious metals like gold (for hedging and risk diversification) increased which served as a safe haven (Mokni et al., 2021). Furthermore, an upswing in the prices of oil was caused by the good news for the vaccine (Bourghelle et al., 2021).

The pandemic crisis also affected the agriculture sector by leading to shortages of labor for on-farm production, harvesting, and processing (FAO, 2020). The decline in consumer spending (due to a decline in income) led to a decline in the demand for agricultural products. The pandemic has threatened global food production as the food supply chain is complex and connects agricultural production with the consumer after going through several processes including “manufacturing, packaging, distribution, and storage”. The pandemic has threatened the smooth functioning of these supply chains (de Paulo Farias & dos Santos Gomes, 2020). Furthermore, the restriction limited the efforts to control locust infestation in East Africa threatening food security in the food-insecure region (Barrett, 2020). Thus, the pandemic led to food insecurity by affecting agriculture. The pandemic also affected the metals & mining market. For example, Gałas et al. (2021) highlighted the risk of supply chain disruption for raw materials due to the

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prolongation of the pandemic. Similarly, Hilson et al. (2021) highlighted the impact of the pandemic on the livelihoods of rural miners in South Africa as they received lower prices for gold than the market prices. Furthermore, Laing (2020) highlighted the decline in prices of metals due to a decline in production activities. Therefore, to avoid risk transmission across markets, it is the need of the present time to understand the impact of the pandemic on different markets including natural resources, agriculture, energy, and metal & mining. However, the empirical linkages between COVID19, and natural resources and commodity sectors are missing in the literature.

Even though a few studies have covered the subject of natural resources by considering the pandemic, they only compare pre-COVID19 and post-COVID19 terms. Among these studies, Mokni et al. (2021) examined the dynamic connectedness among the precious metals in the time of economic uncertainty caused by the pandemic while Gharib et al. (2021) examined the presence of bubbles in oil prices over the pandemic and Atri et al. (2021) examined the effect of COVID19 deaths on oil and gold prices. As far as we know, no study has been focused on the direct relationship of the pandemic with the natural resource index and related sectors. The direct relationship helps us to understand the effect of the outbreak on the sectors under consideration as natural resources and commodity sectors contribute to economic progress and support development. Furthermore, the livelihood of most of the population in developing nations depends on these sectors. Therefore, social distancing measures, lockdowns, and trade restrictions resulting from the pandemic can have an adverse effect on people's livelihood. So, it is important to understand their impact and device policies to cater to such problems not only in the present but in the future as well.

Under the above-mentioned discussions, the objective of this research study is to analyze the time-varying causal relationship between the COVID19 (cases and deaths), and natural resources index and the primary commodity-related sectors: agribusiness, energy, and metals & mining by using the time-varying causality approach for daily data spanning from January 23, 2020, to November 12, 2021. The reason we focus on natural resources is based on the following considerations. Natural resources are closely linked with the economic predicament in comparison to financial assets. Natural resources help investors in risk sharing. Consequently, markets such as the energy sector have become an asset class that is largely exploited for asset diversification, hedging, and speculation purposes. Particularly, global crises such as financial crises, natural hazards, and pandemic crises have considerably increased the significance of natural resource market dynamics. Against this setup, the present study extends the extant literature on COVID19 and natural resource economy in the following manners: First, this is the pioneering study that analyzes the causal associations between the COVID19, and natural resources and commodity sectors. Second, unlike earlier studies that exploit annual data series mitigating data variation within a year, this study exploits a longer horizon of time-daily data-which is more representative. Some studies use daily data, but they prioritize parametric analysis, ignoring time-varying effects. Besides, these studies have mainly focused on the association between precious metals and the role of OVID19 in determining such association, how oil prices and gold prices changed, how volatility increased during COVID19, and many other factors but these studies do not provide evidence of how COVID19 affected natural resources and its related indices using daily data. Third, the study provides a comparative analysis for three related sectors agriculture, energy, and metals & mining. Fourth, the study employed the time-varying Granger causality test proposed by Shi et al. (2018, 2020) based on the rolling window and recursive evolving procedure which is superior because it highlights the date of origin and collapse of causality without detrending or differencing the data. Besides, the time-varying approach is superior as, unlike the parametric approach, it does not disguise time-varying links between the selected variables. For example, the episodes of significant positive and negative influences at various points in time can offset the net influence in the context of parametric estimation, revealing no significant association. Finally, this study provides a global analysis of COVID19 and the natural resource economy nexus.

The study is organized as follows: Section 1 is based on the introduction; section 2 provides a literature review. Section 3 is based on data and methods; section 4 provides empirical results; section 5 provides robustness analysis while section 6 provides the conclusion.

2. Literature review

The pandemic caused nationwide lockdowns and led to the shutting down of many service sectors, restaurants, hotels, tourism, industrial sector, and retail sector along with changes in consumption and production patterns. The pandemic also influenced the measures taken for sustainable development through delays in the supply of basic raw materials required for environmentally friendly technologies, and by increasing medical waste and plastic masks. As natural resources are required for production, the decline in economic activity caused by the pandemic affected this sector as well. Although pandemic affected all economies around the globe however its effects differ across economies. On the one hand, in some economies, the pandemic negatively influenced stock prices and price fluctuations. The bad news about the spread of the pandemic (increasing cases and deaths) created panic among the investors and led to a crisis causing high volatility in asset prices. On the other hand, in some economies, higher risks associated with the crisis also created unique profitable investment opportunities for the participants holding liquidity and investors (Hong et al., 2021). Thus, the pandemic effect on business can be depicted through a change in stock prices which reflect changing "expectations about the future return and risk" (Hohler and Lansink, 2021).

According to Hong et al. (2021) during the COVID19, stock returns became unpredictable and price volatility soared. They argued that pandemic increased profitable opportunities for traders and speculators through escalating market inefficiencies and uncertainties. The US market served as a driving force during the pandemic because a decline in stock prices in the US market was followed by other global markets. The COVID19 has been led to stock market volatility, particularly in economies with a lower level of trust in government and vice versa. Goodell (2020) also highlighted the influence of COVID19 on the stock market. By changing domestic and foreign demand, the pandemic led to economic destruction that witnessed a bailout package of $2.2 trillion in the US which is greater than the bailout package of $750 billion during the global financial crisis. Similarly, Hatmanu and Cautisanu (2021) reported the long-term negative impact of the pandemic on the stock market for Romania using the Bucharest exchange trading (BET) index and applying the ARDL approach on the daily data from March 11, 2020 till April 30, 2021. The pandemic affected oil prices in a number of ways such as 1) through travel restriction, 2) decline in consumer spending, 3) change in economic activity. This caused a decline in oil demand and contributed to a decline in crude oil prices along with the failure of negotiation between Russia and OPEC on oil production cuts. The decline in oil prices crashed other financial markets by increasing market uncertainty (Umar et al., 2021b).

The pandemic affected the agribusiness index as well. This sector also became vulnerable during the pandemic crisis because of the perishable nature of farm products. The pandemic increased market risks by increasing geographical mobility constraints and transportation costs. Besides, the high dependence of the agriculture sector on the labor force for harvesting, processing, and transportation also put this sector at risk. Furthermore, the supply shock including restricted labor mobility, transportation, and inputs availability affected this sector. On the demand side, the consumption patterns changed which negatively affected the companies involved in the food supply chain and threatened food security across the globe (Hohler and Lansink, 2021). As the pandemic disrupted the global supply chain resulting from lockdowns and travel restrictions it led to a decline in oil consumption and demand while an oversupply of oil, storage issues, and OPEC negotiations increased uncertainty in the energy markets (Shaikh, 2022). The higher volatility in the energy market was caused by the uncertainty associated with the pandemic; "from economic policy and financial market uncertainty" (Salisu and Adediran, 2020).

2.1. COVID-19 and natural resource

Literature has focused on how natural resources (price, volatility, and indices) are affected by economic policy uncertainty, geopolitical risk (GPR), financial crisis, and natural calamities. Khan et al. (2021) detected multiple oil bubbles and their originating and ending point using the "Generalized Supermum Augmented Dickey-Fuller (GSADF)" test which coincides with a major crisis. Using Wavelet analysis for the period January 2008 to October 2019, Su et al. (2020a) demonstrated for Venezuela that oil prices lead to inflation in both short and medium-term. The effect of oil prices on inflation is more prominent in the presence of geopolitical instability. The dependence of Venezuela on oil revenues makes it more vulnerable to oil price shocks caused by GPR. Using mixed-frequency vector autoregression (MF-VAR) for China during 1996: Q1 to 2018: Q4, Wang et al. (2021a) indicated that GPR is associated with crude oil insecurity because the GPR increases price volatility and threatens oil security. The study by Qin et al. (2020) examined the time-varying relationship between El Nino and oil prices using wavelet approach for the period 1997:M1 to 2019:M8 and depicted that El Nino has a strong negative impact on oil price over the long run while the positive association is observed over the short and medium-term (as it takes time to respond to the change). They also suggested a positive influence of oil prices on El Nino due to higher emissions associated with oil consumption. Like natural calamities, health emergencies can also influence the natural resources indices.

By employing a full sample Granger causality test on data from 2010:07 to 2020:01 the findings of Su et al. (2020b) demonstrated that shocks originated from oil prices and transmitted to bitcoin prices can be positive and negative. The positive impact suggests the use of bitcoin to avoid risk while the negative effect does not support it. They also reported reverse causality from bitcoin prices to oil prices suggesting that an increase in demand for oil can be threatened by bitcoin prices. Su et al. (2020c) argued that bitcoin prices are positively as well as negatively affected by GPR using rolling window Granger causality for the period July 2010 till December 2019. The positive impact on bitcoin reveals that it can be used to avoid the risk associated with GPR. Bitcoin prices cause GPR positively, so investors can benefit from it through investment optimization in the bitcoin market when GPR is high, as bitcoin prices act as a leading indicator. By employing quantile Granger causality test for BRICS, the study of Su et al. (2021) reported that supply shocks in oil markets increased economic policy uncertainty in China, India and Brazil, while a decline in oil prices (crude) affected economic policy uncertainty in Russia and South Africa. Thus, the effect of oil prices on EPU in BRICS is asymmetric. The study of Su et al. (2020d) documented a negative association between oil prices and wage arrears, and wage arrears and oil prices for Russia using bootstrap rolling window Granger causality test for the period from January 1997 to August 2019. By employing bootstrap ARDL with Fourier function, the study of Wang et al. (2021b) for net oil-importing economies revealed the existence of long-run relationship between carbon emissions, oil demand, and military strength in the case of China and India while no cointegration relationship is reported in case of US, France, and other economies.

Recently the literature is paying attention to the association between COVID19 and natural resources. Mokni et al. (2021) analyzed the dynamic connectedness between precious metals prices (gold, palladium, platinum, and silver) and economic policy uncertainty before and over the COVID-19 crisis using Quantile-VAR (Q-VAR) approach covering the data spanning from January 2, 2015, to December 3, 2020. They provided evidence of a dynamic association between the metals. Moreover, they showed that an increase in the spill-over effect is observed during extreme market conditions. The risk diversification investors invested in precious metals to optimize investment returns during the pandemic period. They also reported that gold acts as a safe haven asset (as a hedge) during uncertain market conditions while other metals show heterogeneous responses to the pandemic.

The study of Gharib et al. (2021) examined the dynamic bubbles of oil prices and predicted their crash times using the data from November 1, 2019, to December 31, 2020, by applying "Log Periodic Power-Law Singularity (LPPLS) and Discrete Scale LPPLS bubble indicators". Their findings suggested that the COVID19 declined the prices of West Texas Light crude oil (WTI) and Brent crude oil. They attributed such barrel price fall to demand and supply imbalances because the global industrial production slowed down in response to lower demand caused by COVID19. However, this is not the only factor held responsible for the decline in prices as Oil price War between Saudi Arabia and Russia is also a significant contributor to this decline. Similarly, Bourghelle et al. (2021) reported that the COVID19 pandemic affected all economies around the world through a negative effect on the oil industry. The COVID19 impacted the oil industry through the demand and supply shocks. The decline in demand for crude oil (resulting from lockdowns) triggered economic recession while supply shock led to an oil trade war between Saudi Arabia and Russia. Russia refused to reduce oil production to keep oil prices at a moderate level due to disagreement with Saudi Arabia on oil production cuts and the crisis exacerbated in March 2020 (Gharib et al., 2021). These uncertainty-based shocks led to high volatility in oil prices and associated markets.

Lahiani et al. (2021) examined the asymmetric effect of 5 precious metals (Aluminum, Platinum, Palladium, Copper, Gold) and the S&P 500 stock market index covering the pandemic period. The results suggested that the precious metals do affect S&P 500 stock market index as an increase in prices of precious metals is associated with an increase in S&P prices while a decline in precious metals does not affect S&P prices over the long run (in case of aluminum and platinum). Their findings reveal that over the long run, the relationship between S&P and precious metal prices is stickier upward supporting asymmetric co-movement. The effect of aluminum is asymmetric while platinum, palladium, copper, and gold affect S&P 500 stock market index in an asymmetric manner. Although, Palladium, copper, and gold act as a safe haven over the short run while none of these metals act as safe heaven over the long run. The study of Atri et al. (2021) analyzed the effect of health crises (COVID 19) on gold and oil prices using the ARDL estimation technique for the data spanning over January 23, to June 23, 2020. They reported a negative impact of Covid-19 deaths on oil price in the short run while a positive impact over the long run. They reported a positive long-run association between Covid-19 cases and gold prices while a positive short-run association between COVID19 deaths and gold prices. Furthermore, the relationship varies depending on consideration of the disease as epidemic or pandemic. Devpura and Narayan (2020) also reported an increase in oil price volatility between 8 and 22% resulting from COVID19 cases and deaths. The change in natural resources prices has varying impacts on economies and financial sectors. In this regard, while analyzing the resource curse hypothesis for twelve oil producing economies for quarterly data spanning over 2001: Q1 to 2019: Q4 by employing panel regression, the study of Umar et al. (2021a) revealed that oil price boom is associated with banking inefficiency and increased risk of default. Therefore, promoting economic stagnation and resource trap. Zhang (2021) reported the positive impact of COVID19 on oil stock volatility in China using an autoregressive conditional heteroskedasticity model for the period spanning from July 8, 2019, till July 5, 2021. By employing the "Generalized Supermum Augmented Dickey-Fuller approach" the findings of Umar et al. (2021b) supported the presence of multiple bubbles in the oil market during different periods using data from January 2000 to December 2020.

Although the above-discussed studies have examined how the pandemic has affected oil and gold prices (Atri et al., 2021), dynamic connectedness among precious metals (Mokni et al., 2021), bubbles in oil prices, and their crash time (Gharib et al., 2021; Umar et al., 2021b), oil industry (Bourghelle et al., 2021; Zhang, 2021), linkages between precious metals and S&P stock market index (Lahiani et al., 2021), shock transmission between oil and cryptocurrency markets (Su et al., 2020b), GPRk and cryptocurrency (Su et al., 2020c), oil and economic policy uncertainty (Su et al., 2021), oil prices and wage arears (Su et al., 2020d). However, none of these studies explored the direct casual impact of the outbreak on natural resource index and related sectors.

2.2. COVID-19 and agribusiness equity

Like natural resources, the agriculture sector (AGR) is important for the economy for multiple reasons including provision of food, employment, income, and exports among others. This sector is also affected by the uncertainty caused by the pandemic. To examine the impact of the health crisis (COVID19) on the agriculture sector, the study of Elleby et al. (2020) conducted the scenario-based analysis and supported a decline in meat and dairy prices by 7–18 and 4–7% respectively. They also reported that due to a decline in the use of transport and oil prices, biofuel lost its competitiveness against oil. The demand for biofuel is strongly associated with transport fuel and changes in oil price caused by pandemic (lockdowns across countries) led to a decline in demand for transport fuel and a fall in international oil prices making biofuels less competitive with fossil fuel. By using the global multicommodity agriculture market model they reported that although supply disruption led to food insecurity in developing countries, however food consumption remains unaffected at the global level due to inelastic demand for agricultural products and a short period of shock. Furthermore, production requires several years to adjust to the price change. The commodities whose production is affected most by the pandemic are high value-added products including meat, dairy products, and biofuels. They also reported a decline in CO_2 emissions by 50million tons from the agriculture sector between 2020 and 2021. Hohler and Lansink (2021) examined 71 companies in food supply chain from stock indices in US, Japan and Europe and reported increased prices volatility in food supply chain companies over the period 2000–2020. High volatilities were shown in the stock prices of fertilizer manufacturers, agrochemicals, and food distributors while low price volatility was observed in food retailers' stocks. They also reported increase in returns of profitable companies during the pandemic in the US, Japan, and Europe.

The study of Ruan et al. (2021) for China highlighted the increase in prices of vegetables due to lockdown measures taken to contain COVID19 when compared to normal years where the price fluctuations were normal using "time discontinuity design method (T-RD) and difference in difference method (DID)". The highest prices were recorded in week four of lockdown measures while prices returned to normal level by week11. They observed an incline in prices due to the resurgence of COVID19 in some provinces, but it returned to a normal level (week15) due to the removal of lockdown measures. They reported supply chain disruption as the cause behind the price hike. Yan et al. (2021) reported an incline in prices of agricultural products by 20 percent during the pandemic. The price volatility observed in agriculture products was due to trade restrictions imposed to cope up with the problem of the pandemic that led to 22% volatility in world agriculture prices during the COVID19 pandemic.

Ahmed et al. (2021) examined how COVID19 had an impact on the agriculture sector in Bangladesh, India, and Pakistan. They asserted that the pandemic hurt agricultural production and the vulnerable livelihood of agricultural laborers. The restricted mobility caused by lockdowns created difficulties to purchase inputs along with the selling of products. Furthermore, livestock, vegetables, fruits, and fishing sectors were affected more than the crop sector. Chenarides et al. (2021) highlighted the impact of the COVID19 crisis on the US food supply chain. Although being the most efficient, productive, and safe food industry in the world it lacks resilience (reallocate output). The consumption patterns changed and shifted from perishable to non-perishable products thereby ending up in food supplies in foodbanks and landfills (inflexible supply chain). However, according to Gray (2020), the Canadian agricultural supply chain was not disrupted but has improved due to the decline in demand for transportation from the non-agriculture sector during the COVID19 pandemic. As the decline in demand for transportation from the non-agricultural sector, increases the availability of crew and locomotives for potentially available agricultural products. Furthermore, due to the importance of agricultural products in the food supply chain, restrictions and closures were not imposed on that sector, however, they did follow social distancing protocols to avoid direct contact and spread of the pandemic.

From the discussion it can be concluded that studies are examining how the pandemic affected food consumption (Elleby et al., 2020), stock price volatility in food supply chain (Hohler and Lansink, 2021), decline in food away from home expenditure in the US (Beckman and Countryman, 2021), changes in the prices of vegetables in China (Ruan et al., 2021), agricultural price volatility (Yan et al., 2021), disruption in agricultural production and the vulnerable livelihood of agricultural laborers in South Asia (Ahmed et al., 2021), and food supply chain disruptions (Chenarides et al., 2021). However, these studies lack evidence on how the COVID19 affected the agriculture sector in general and agribusiness indices in particular. In addition, most of these studies are qualitative in nature.

2.3. COVID19 and energy

Energy plays a crucial role in the development of economies and is required for production and consumption. Like other sectors of the economy, the energy sector is also disrupted by the pandemic. The uncertainty caused by COVID19 effected energy markets in the form of higher volatility. Furthermore, the increase in COVID19 cases affected investors sentiments as they became worried about the protection of their energy investment. The higher level of volatility in the energy market reflects the sensitivity of returns from the systematic risk and the "shortage of future and options line" (Shaikh, 2022). Navon et al. (2021) also highlighted that the COVID19 crisis led to a load shift from the industrial and commercial sector to the private sector. The decline in demand of electricity consumption from industrial and commercial sectors poses several challenges including high voltage, inaccurate load forecasting, high renewable energy share (frequency fluctuations and high ramp rates) for system operators and electric utilities. The energy demand from the private sector increased. However, due to social distancing measures, most of the population residing in urban areas migrated to rural areas causing an increase in forecasting error (uncertain load prediction). They suggested the use of machine learning-based algorithms to assist system operators during a crisis. Zhong et al. (2020) also reported a decline in electricity demand due to lockdown restrictions imposed by different governments around the world. The pandemic has influenced the energy market through a change in load profile and composition. Although the total electricity generation declined however renewable energy generation has increased. The challenges faced during the crisis include voltage violation, system maintenance, and management challenges.

The study of Salisu and Adediran (2020) also highlighted the role of uncertainty caused by COVID19 in determining energy volatility by utilizing the data from March 21, 2011 till June 4, 2020. The findings reveal increase in energy market volatility and uncertainty during the pandemic implying positive association. The market uncertainty is caused by economic and financial uncertainty. The findings of Christopoulos et al. (2021) employing panel data model spanning over daily data from January 21, 2020, to May 13, 2021, reported oil price volatility caused by COVID19 deaths and uncertainty (associated with the pandemic). Furthermore, they reported that COVID19 death and growth in death rate caused by the pandemic explains 11% and 39% oil volatility.

Aloui et al. (2020) used the data from January 2, April 9, 2020, using "time varying coefficient and stochastic volatility model" and reported time varying impact of pandemic shocks on energy future markets including crude oil and natural gas indices. The results confirm the time varying impact of pandemic on energy commodities indices. They split the data into three time period one before COVID19 was declared pandemic, second when it was declared pandemic and caused stock market crash and led to increase in oil and gas indices this is because of shift in investment by speculators from equity market to commodity market. The reason behind shift to future commodity market is they are less risky with higher profitability than equity market. Third period when oil index showed a decline, and the probable reason could be the spread of pandemic in the US.

Nyga-Łukaszewska and Aruga (2020) analyzed the impact of COVID19 cases in US and Japan on energy markets considering oil and gas prices. By employing ARDL method the results revealed that COVID19 cases lead to decline in oil prices while increase in gas prices in the US. In Japan the negative effect was observed in oil prices with a lag of two days. Zhang and Hamori (2021) using time and frequency domain approach for the US, Japan and Germany over the period from January 4, 2006 to August 31, 2020, reported occurrence of return spillover in the short run while volatility spillover during the long-run in oil and stock market. COVID19 increased risk causing decline in oil prices and initiating US stock market crash and resulted in loss of investors trust during the short run. They reported that the effect of pandemic on oil and stock market is more severe than the global financial crisis of 2008.

The limited literature available on EGY and pandemic linkages examines; supply chain disruptions in energy sector (Pradhan et al., 2020), load shifting, high voltage, inaccurate load forecasting, high renewable energy share (Navon et al., 2021), voltage violation, system maintenance and management challenges (Zhong et al., 2020), energy market volatility and uncertainty (Salisu and Adediran, 2020), oil price volatility (Christopoulos et al., 2021), time varying impact of pandemic shocks on energy future markets including crude oil and natural gas indexes (Aloui et al., 2020), oil and gas prices (Nyga-Łukaszewska and Aruga, 2020), and oil and stock market (Zhang and Hamori, 2021). None of these studies examined how the relationship between the COVID19 and energy is varying over time.

2.4. COVID19 and metal and mining

Metal & mining is also an important sector of the economy and is not free from the disruptions caused by the COVID19 crisis. Gałas et al. (2021) analyzed how COVID19 influenced the metal and mining industry. According to their findings, COVID19 affected feasibility studies of project implementation and development of new mines. The pandemic has a medium impact on the exploration and discovery stage while the impact of the pandemic on current mining is small and short-run due to compensation of high demand of minerals from China (low demand from other parts of the world). However, ceasing new mines exploration and development will have a long-run disrupting effect on the supplies of raw material.

Hilson et al. (2021) highlighted the impact of COVID19 on artisanal and small-scale mining activities (ASM) in Sub-Saharan Africa as most of the rural population is associated with this mineral extraction and processing activity which has the potential to support rural development has been affected by the pandemic. The prices they received for gold were lower than market prices due to being cut off from the international markets. Furthermore, lockdown measures have reduced labor, capital, and equipment mobility causing a decline in productivity as well. Laing (2020) also highlighted that the demand for metals and minerals has declined because of the contraction of demand from industrial production and construction. As a result, metals prices fell between March and April 2020 having a severe impact on aluminum and copper. Along with declining prices, the mining activities have been affected by the pandemic in the form of suspension of non-essential operations due to government regulations, positive cases, and shutdowns. Hence, increasing the costs of capital associated with future mines re-opening. Calvimontes et al. (2020) highlighted that COVID19 increases conflict and cooperation in small-scale gold mining in the Brazilian Amazon. On one hand, it adds challenges on the other hand self-organization of garimpeiros (small scale gold miners) to find alternative solutions to the crises (to survive alternative solutions were provided so that the mines continue operations due to high dependence of people on these activities for livelihood).

The extinct literature on the effect of pandemic on metal & mining explains; disruption of feasibility studies and development of new mines (Gałas et al., 2021), decline in gold prices to the miners and decline in productivity (Hilson et al., 2021), fall in prices of metals and minerals associated with a decline in demand due to lockdown measures, suspension of non-essential operations (Laing, 2020), challenges and opportunities in the form of reorganization (Calvimontes et al., 2020), however, none of these studies examined the causal linkages associated with the COVID19 over the course of time.

Although the literature is developing on the impact of COVID19 on different sectors of the economy and some studies have provided evidence on the influence of the pandemic before and after the crises, however, none of the studies attempted to explore the causal linkages between COVID19 and related sectors: agriculture, energy, and metals & mining. Therefore, it is important to examine how the pandemic affected different sectors of the economy to understand its impact on the environment and sustainable development. The present study fills these research gaps by analyzing the nexus of COVID19 and natural resources and providing evidence from time-varying causality.

3. Data and methods

3.1. Data

To analyze the causal relationship between the pandemic, and natural resources, energy, agriculture, and metal & mining, we use the following indices: S&P global natural resources (NAT), S&P global agribusiness equity (AGR), S&P 300 metals & mining (MM) and S&P global 1200 Energy (EGY); and the number of cases (C-COVID19) and deaths (D-COVID19). The study examined the impact of COVID19 pandemic on natural resource index and related commodity indexes where S&P global natural resources (NAT) includes 90 of the largest publicly traded companies in natural resources and commodities businesses: agriculture, energy and metals & mining. S&P global agribusiness equity (AGR) includes 24 of the largest publicly-traded agribusiness companies from around the world S&P 300 metals & mining (MM) includes companies that are classified by the Global Industry Classification Standard (GICS®) as being in the Metals & Mining industry, which includes producers of aluminum, gold, steel, precious metals and minerals. S&P global 1200 Energy consists of all members that are classified within the energy sector. The data are index based on relevant firms from the world, and the covid-19 case & death numbers are worldwide; not related to a country or group of countries. The data are drawn from the Datastream (www.refinitiv.com/en). The length of daily data is from January 23, 2020, to November 12, 2021(660 observations). It should be noted that the data on COVID19 are not available before this indicated date. Table 1 presents the correlation analysis, and it can be seen from the correlation that the indices are positively linked.

The trends of analyzed variables are presented in Fig. 1 which suggests that data on global natural resources, agribusiness equity, metals & mining, and energy follow a downward and upward trend while the number of COVID19 cases and deaths caused by COVID19 show volatility over the study period. It can be observed from the series that NAT, AGR, EGY, and MM are at their lowest levels in April 2020 with fewer cases of COVID19 while the death rate caused by COVID19 ranges between 5000 and 10000, respectively. After this period an upward fluctuating trend is observed in all series. After reaching a peak in April 2021, NAT and AGR start declining however EGY shows upward

Table 1
Correlation analysis.

	NAT	AGR	EGY	MM	C-COVID19	D-COVID19
NAT	1.0000					
AGR	0.9808*	1.0000				
EGY	0.8440*	0.7689*	1.0000			
MM	0.8765*	0.8570*	0.5686*	1.0000		
C-COVID19	0.6907*	0.7564*	0.2835*	0.7609*	1.0000	
D-COVID19	0.5919*	0.6485*	0.1974*	0.6923*	0.8613*	1.0000

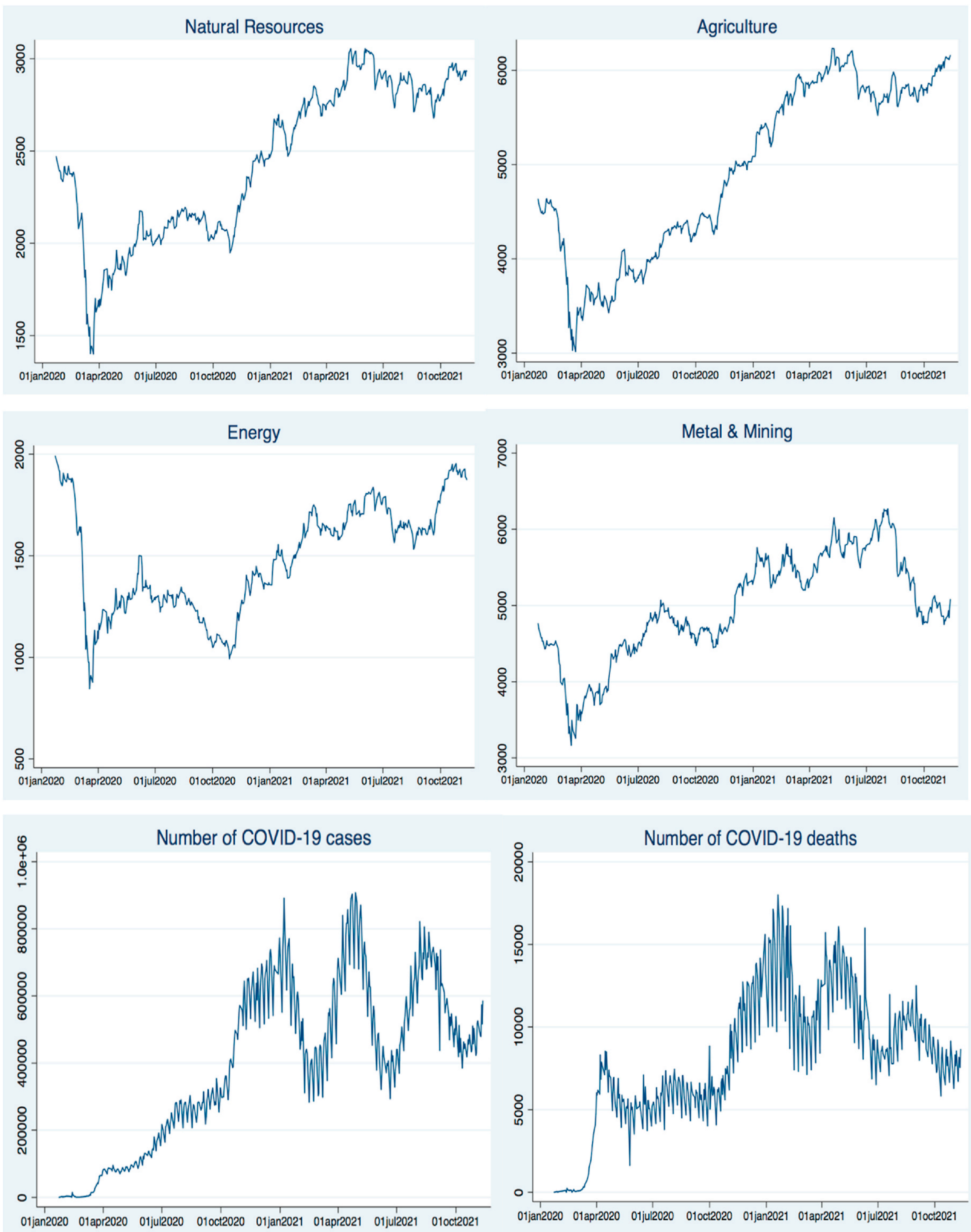

Fig. 1. Time plots of variables under investigation.

movement with a decline in July 2021, while MM achieved a peak in July 2021 and after that start declining. The C-COVID19 were at the peak in January, April, and August 2021 with minimum cases being reported in February and July 2021. The D-COVID19 was highest during January 2021 while declined afterward with few spikes upward during April and June 2021. Thereby validating the use of the time-varying approach in exploring the linkages among these variables.

3.2. Methods

This study adopts the novel time-varying methods due to Shi et al. (2018, 2020) to examine the causal relationship that whether NAT, AGR, MM, and EGY are Granger caused by C-COVID19 and D-COVID19. The test examines the alternate hypothesis of parameters being significant over the whole or a point of time. The causality test provides the result of three procedures including forward, rolling window, and recursive evolving causality. The forward and rolling window procedures are based on Wald statistics while the recursive evolving algorithm is based on a subsample of sup Wald statistics. The recursive procedure is based on the recursive calculation of the related test statistics, in a backward expanding sample sequence in which the final observation is the observation of interest. The procedure is called recursive evolving algorithm as the inference regarding the existence of causality is based on the final observation "which depends on supremum taken over values of all the test statistics in the entire recursion". The recursive evolving procedure endogenously determines the change points i.e the date of origin and collapse of causality and change in direction of causality within the sample data without the need of detrending data and it also allow for heteroscedasticity (Shi et al., 2018, 2020). As trend play an important role in determining causal relationship (either deterministic or stochastic) and differencing or detrending may lead to specification bias. Therefore, to avoid this bias, Shi et al. (2020) provide evidence of preference of the methods that do not require detrending or differencing over the methods that does, and as causal relationship can change over time therefore the relationship between the variables can be time sensitive (Shi et al., 2020). Therefore, this methodology does not require priori knowledge regarding the non-stationarity (or stationarity) of the time series and is robust to the integration and cointegration properties of the time series. Furthermore, the three procedures (forward, rolling, and recursive evolving) are based on "lag-augmented vector autoregressive framework (LA-VAR)" which follows chi-squared distribution, and its performance is better in terms of size stability when compared to fully modified VAR and VECM. However fully modified VAR and VECM has higher power than LA-VAR. The results obtained from the recursive procedure are reliable followed by the rolling window algorithm while the power of forward recursive test is far below rolling and recursive procedures (Shi et al., 2020), therefore, following Raggad (2021), we only reported the results obtained from rolling window and recursive algorithm. As relationship between variables can change over time, unlike parametric approach the time varying causality does not disguise the time-varying relationship between the selected variables. Therefore, it is important to examine that how the causal relationship specifically between COVID19 and natural resource and its three indices (AGR, EGY and M&M) vary overtime.

4. Empirical results

First, we apply two different unit root tests; namely, the Zivot-Andrews test with a structural break (ZA) proposed by Zivot and Andrews (2002) and Phillips-Perron (PP) proposed by Phillips and Perron (1988), to determine the order of integration of the variables under investigation. Table 2 indicates that all the variables (NAT, AGR, MM, EGY, C-COVID19, and D-COVID19) are stationary at first difference i.e I(1). Before applying time-varying Granger causality it is important to know about the order of integration of variables under consideration. This methodology does not require differencing or detrending of data as it uses robust econometric procedures for different integration and cointegration properties of the variables.

Table 2
Results from unit root tests.

	Levels		First-differences		Outcome
	ZA	PP	ZA	PP	
NAT	−4.15	−0.73	−19.97*	−19.77*	I(1)
AGR	−3.92	−0.29	−13.62*	−21.29*	I(1)
EGY	−4.08	−1.83	−8.59*	−20.64*	I(I)
MM	−4.53	−1.33	−22.75*	−22.55*	I(I)
C-COVID19	−3.25	−2.17	−11.51*	−39.81*	I(I)
D-COVID19	−2.66	−4.10*	−15.25	−53.56*	I(I)

Note: * represents a 1% level of significance.

The time-varying Wald test statistics and their bootstrapped critical values are shown in Figs. 2–5. A significant causality is confirmed when the Wald sequence exceeds the corresponding critical value. Fig. 2 displays the causality between COVID19 and natural resources (NAT). The left panel examines whether NAT is caused by C- COVID19. The results obtained from rolling window (a) provide evidence of causality as the value of test statistics is above the critical value at several points in time. However, the results do not suggest any causality between the observed variables at certain points such as July 30, 2020, in September, October 2020, April 2021, and Mid-August. While examining the results obtained from the recursive evolving procedure (panel b) it is evident that strong causality is supported from C- COVID19 to NAT as, during most of the period under consideration, the value of test statistics is above the critical value. However, volatility is observed as evidence of no relationship is observed between October 20, 2020 to January 20, 2020 and between September 2021 and October 2021 respectively. The evidence of a strong relationship between C-COVID19 and NAT is provided by the recursive procedure when compared to the rolling window. As suggested by Shi et al. (2018) the recursive evolving procedure performs well in the finite sample when compared to the rolling window procedure. Therefore, it can be said that NAT is Granger caused by C-COVID19.

The right panel of Fig. 2 shows the causality between NAT and D-COVID19. The rolling window (panel a) provides evidence of causal relationship over the whole period with few spikes below the critical value, representing volatility in the causal relationship. To be more specific during a few periods (July 20, 2020, August 2020, and from July 2021 to October 2021) the value of test statistics is below the critical value and suggests no causal association. The recursive evolving provides (panel b) provides evidence of a strong causal relationship between NAT and D-COVID19. Thus, NAT is Granger caused by D-COVID19. The impact of D-COVID19 on NAT is more profound than C-COVID19, as the death rate increases the imposition of lockdowns, social distancing measures, and trade restrictions (restricting exports) undermine the ability to extract and export natural resources. The pandemic led to a decline in global industrial production, thereby causing a decline in oil consumption and barrel prices, due to demand-supply imbalances (Gharib et al., 2021). Similar to our findings, Mokni et al. (2021) also reported that pandemic affects natural resources. Their findings suggested that the pandemic influenced the dynamic connectedness among the precious metals through shock transmission. The investors preferred portfolio diversification during the COVID19 crisis to avoid risk and Bourghelle et al. (2021) also highlighted the impact of the pandemic on the oil industry. The pandemic caused panic among the investors leading to the high volatility and decline in asset prices (Hong et al., 2021). The US stock market served as a leading indicator for the global market as decline in stock prices in US was followed by other global markets. Hatmanu and Cautisanu (2021) also reported long term negative impact of pandemic on stock market. The uncertainty caused by pandemic led to shocks in oil market which increased economic policy uncertainty. Furthermore, in April 2020 during the pandemic, oil prices decreased to a negative number (Umar et al., 2021b). Devpura and Narayan (2020)

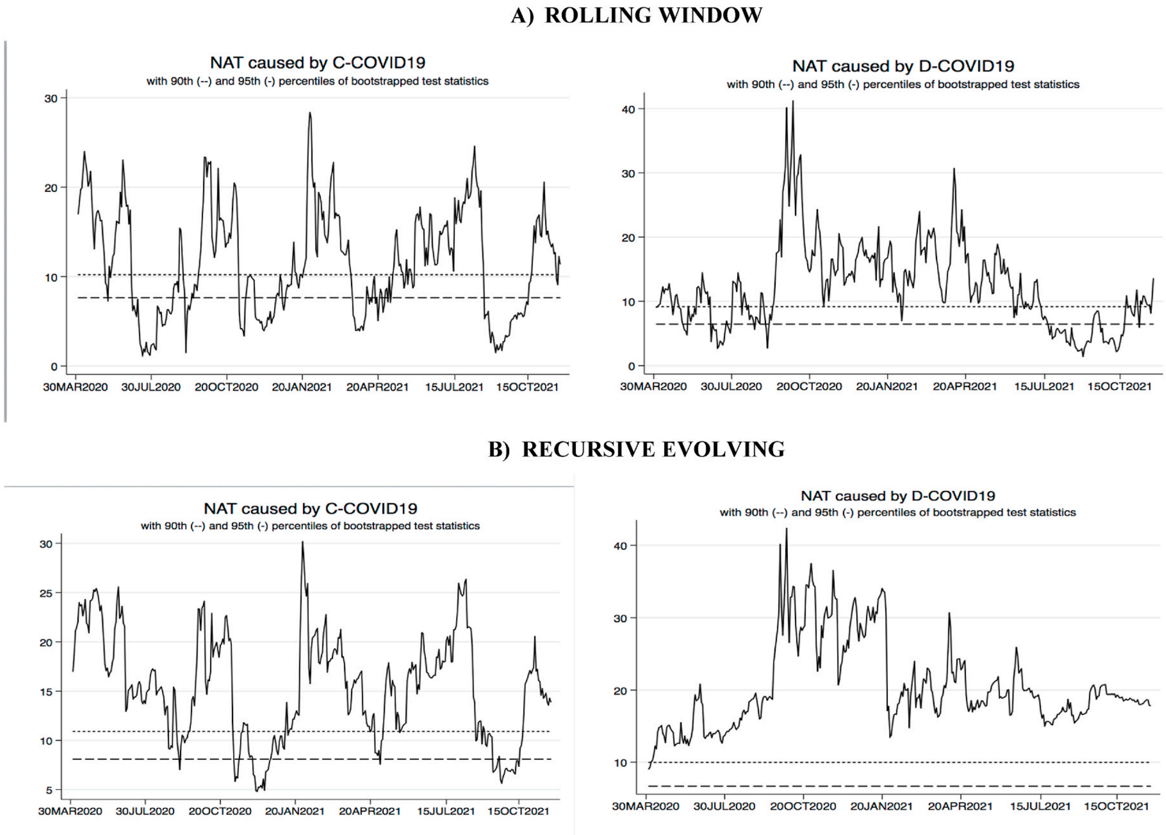

Fig. 2. Is natural resources Granger-caused by COVID-19?.

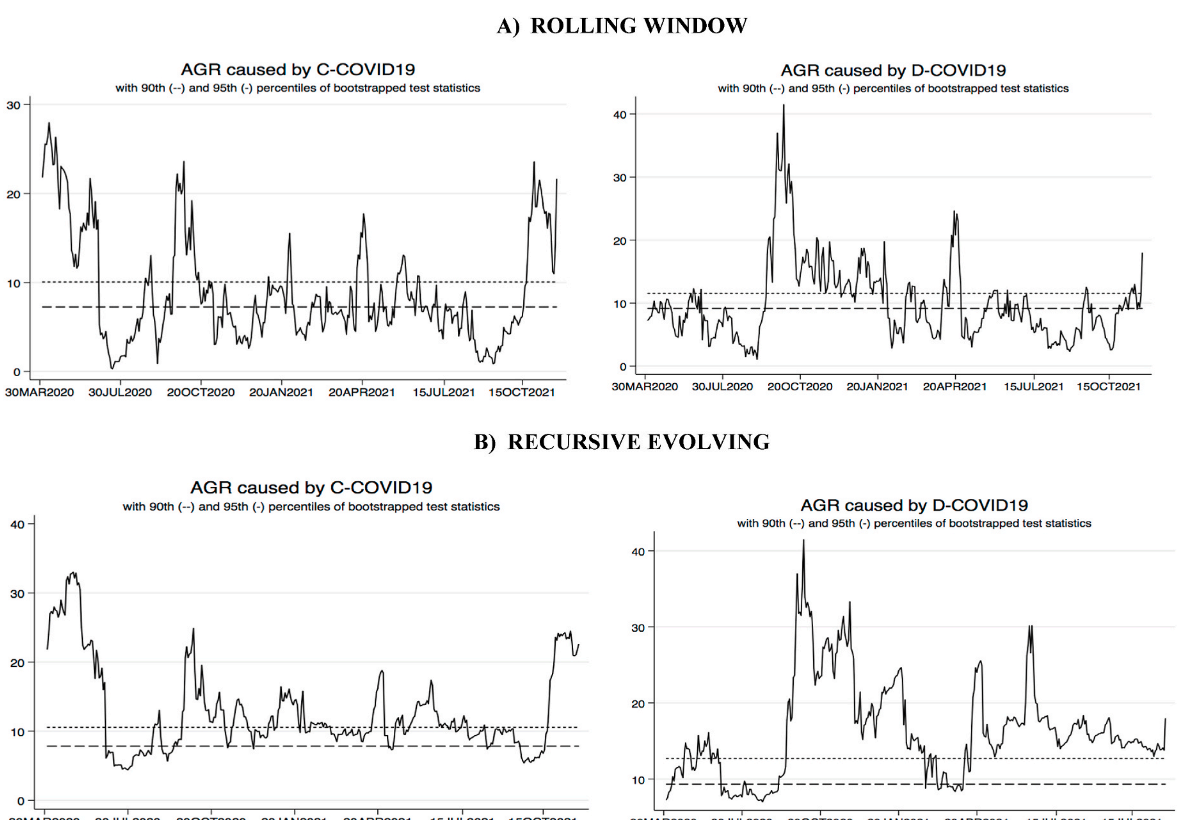

Fig. 3. Is agriculture Granger-caused by COVID-19?.

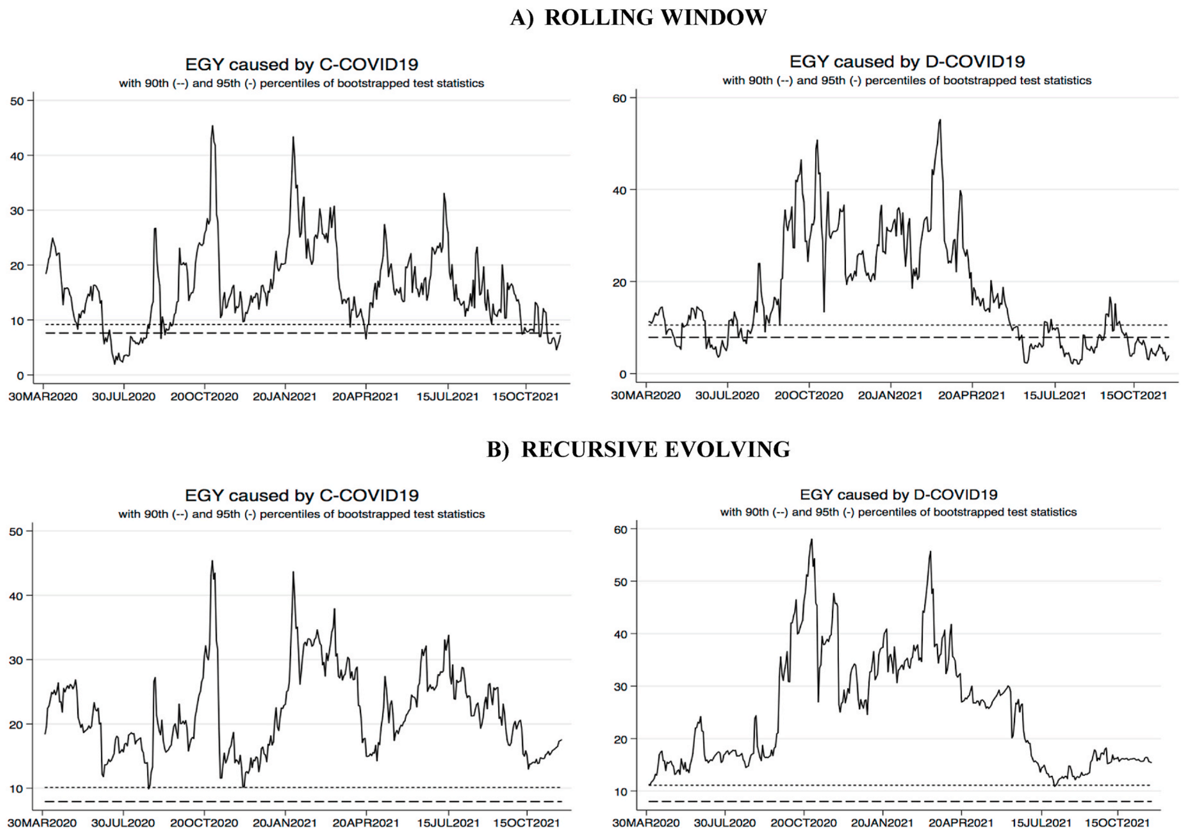

Fig. 4. Is energy Granger-caused by COVID-19?.

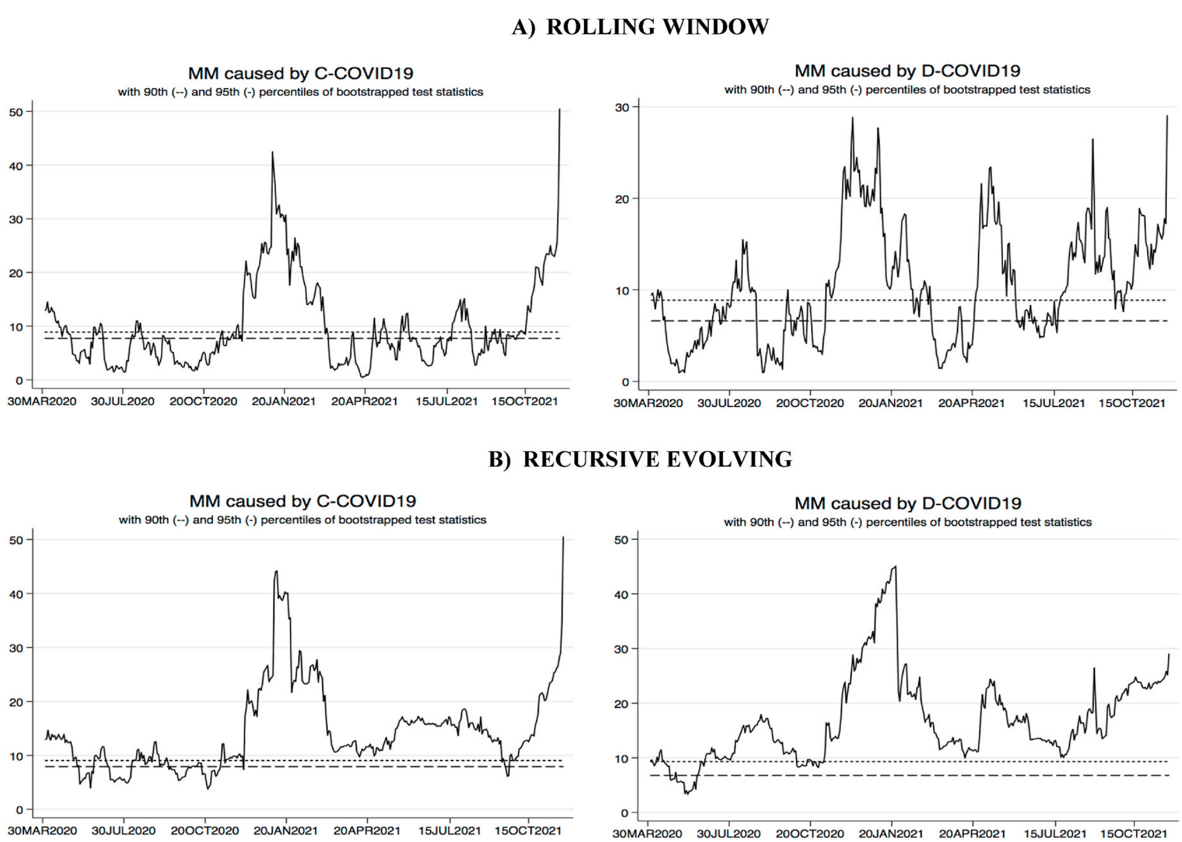

Fig. 5. Is metal & mining Granger-caused by COVID-19.

also reported increase in oil price volatility between 8 and 22% resulting from COVID19 cases and deaths. The pandemic affected oil price volatility through demand side due to restrictions on travel and decline in production in China and Europe (Sharif et al., 2020). Therefore, COVID19 causes natural resources as uncertainty in the market led to volatility in stock markets.

Fig. 3 represents the causal relationship between C-COVID19 and AGR (left panel) and D-COVID19 and AGR (right panel). The results obtained from the rolling window (left panel of a) of Fig. 3 suggest volatility between the C-COVID19 and AGR relationship as the value of test statistics is below the critical value during several periods. Contrary to this, the value of test statistics is above the critical value as well, therefore, the null of no causal relationship cannot be accepted due to episodes of causal linkages. Although volatility is depicted by recursive evolving procedure, however, the recursive procedure provides strong evidence of causal linkages between C-COVID19 and AGR. The duration of the relationship is longer as suggested by the recursive evolving procedure when compared to the rolling window procedure. Similarly, the right panel show linkages between D-COVID19 and AGR, and evidence of stronger causality is reported by recursive procedure when compared to the rolling window procedure. There are episodes of fluctuation which leads to a weak relationship however the results support that AGR is Granger caused by D-COVID19. The pandemic causes AGR. The pandemic led to food supply chain disruption in the US (Chenarides et al., 2021) and a decline in food away from home expenditure in the US (Beckman and Countryman, 2021). Similarly, Ruan et al. (2021) also highlighted that lockdown led to an increase in prices of vegetables (because of a pandemic) in China, however, Gray (2020) reported the resilience of the Canadian agricultural supply chain during the pandemic as transportation and crew that was free from other sectors were used in the agriculture sector to avoid disruptions. Hohler and Lansink (2021) reported high volatility in the stock prices of fertilizer manufacturers, agrochemicals, and food distributors while low price volatility was observed in food retailer's stocks.

Fig. 4 represents the causal relationship between C-COVID-19 and EGY (left panel) and D-COVID-19 and EGY (right panel). The results obtained from the rolling window (left panel) of Fig. 3 suggests that a causal relationship exists between C-COVID-19 and EGY as the value of test statistics is above the critical value for the whole period except on July 30, 2020 and October 15, 2021 where the values (of test statistics) is below the critical value indicating no relationship during these periods, however, the null of no causal relationship cannot be accepted due to episodes of causal linkages. Although the recursive evolving procedure also depicts volatility, however, the value of test statistics is above the critical value for the period under consideration in contrast to the spikes suggested by the rolling window. The increase in number of cases led to increase in measures to contain the virus including social distancing, lockdowns which affected the energy demand and supply due to variation in load demand and forecasting errors. So, it can be said that C-COVID-19 causes EGY as the evidence supports causal linkages. Similarly, the right panel shows the causal linkages between D-COVID-19 and EGY. The rolling window provides evidence of a volatile relationship while the recursive evolving procedure support that EGY is Granger caused by D-COVID-19 during the whole period. Pradhan et al. (2020) also highlighted the supply chain disruption in the energy sector as most of the raw material was imported from China and closure of parent industries affected energy sector transition. Navon et al. (2021) highlighted the shifts in energy consumption pattern due to the pandemic and challenges faced by system operators and electric utilities. During the crisis challenges including voltage violation, system maintenance and management challenges were also highlighted by Zhong et al. (2020). Nyga-Łukaszewska and Aruga (2020) also reported decline in oil prices while incline in gas prices in the US, and a decline in oil prices with a lag of two days in Japan caused by the pandemic. Aloui et al. (2020) reported time varying impact of the pandemic on energy commodities indexes. Similarly, Salisu and Adediran (2020) reported higher energy market volatility during the pandemic. Similarly, Shaikh (2022) also reported volatility in the energy and commodity market. The pandemic resulted in negative returns in energy and commodity market. Thus, COVID19 causes EGY. Fig. 5 presents the causality from C-COVID19 and D-COVID19 to MM. Left panel shows volatility in the relationship as suggested by the rolling window while the recursive procedure paints a different picture and provides evidence of strong causal linkages from C-COVID19 to MM. On the other hand, in the right panel, the rolling window (right panel) provides evidence of volatility in the relationship between D-COVID19 and MM during the initial and at the end of the period while a strong relationship is depicted in the middle of the period. The recursive procedure supports causal linkages over the whole period. Thus, it can be concluded that MM is Granger caused by C-COVID19 and D-COVID19. Our findings are like Gałas et al. (2021) as they reported feasibility studies of new projects (mines) and development of new mines is affected by the pandemic. Similarly, Hilson et al. (2021) also reported decline in productivity in mining sector due to lockdowns that restricted labor, capital, and equipment mobility. Likewise, Laing (2020) reported decline in demand for metals and minerals due to decline in production resulting from the pandemic.

5. Robustness checks

To double-check the robustness of the outcome on Granger causality presented in Figs. 2–5, an additional analysis is carried out by estimating the heteroskedastic consistent test statistics. The results are reported in Figs. 6–9. Fig. 6 panel a) shows the result obtained from heteroskedastic-robust specification from rolling window procedure for C-COVID19 and D-COVID19 to NAT. In the left and right panel, the test statistics sequence is above the critical value sequence for most of the sample period suggesting the existence of causality from C-COVID19 and D-COVID19 to NAT. Similarly, the recursive evolving procedure also depicts, the test statistics sequence to be above the critical value sequence for most of the period for C-COVID19 and NAT relationship while for the whole sample period for D-COVID19 and NAT causality thereby supporting the existence of causality from C-COVID19 and D-COVID19 to NAT. The recursive evolving procedure suggests a longer duration of relationship among the variables when compared to the rolling window procedure. Fig. 7 panel (a) shows the causality result obtained from the rolling window heteroskedastic-robust specification for C-COVID19 and D-COVID19 to AGR. The rolling window shows the volatility in the relationship between the variables while recursive evolving heteroskedastic robust specification (panel b) shows the test statistics sequence to be above the critical value sequence for the most period for C-COVID19 and AGR relationship while above the critical value for the whole periods for D-COVID19 and AGR causality. The results support the existence of causality from C-COVID19 and D-COVID19 to AGR. The recursive evolving procedure suggests a longer duration of relationship among the variables compared to the rolling window procedure (which shows higher volatility depicting its weakness to capture the causal relationship at different points captured by the recursive evolving procedure). Fig. 8 panel (a) and (b) shows the result obtained from heteroskedastic-robust specification from rolling window and recursive evolving procedure showing causality from C-COVID19 and D-COVID19 to EGY. In the left and right panel, the rolling window shows that the heteroskedastic robust test statistics sequence is above the critical value sequence for most of the sample period (with few fluctuations) suggesting the existence of causality from C-COVID19 and D-COVID19 to EGY. The recursive evolving procedure also depicts that the heteroskedastic robust test statistics sequence is above the critical value sequence for the whole period under consideration for both causal linkages (C-COVID19 and EGY and D-COVID19 and EGY). Thereby supporting that EGY is Granger caused by C-COVID19 and D-COVID19.

Fig. 9 shows the result obtained from rolling window (a) and recursive evolving (b) heteroskedastic-robust specification for causality from C-COVID19 and D-COVID19 to MM. The results obtained from the

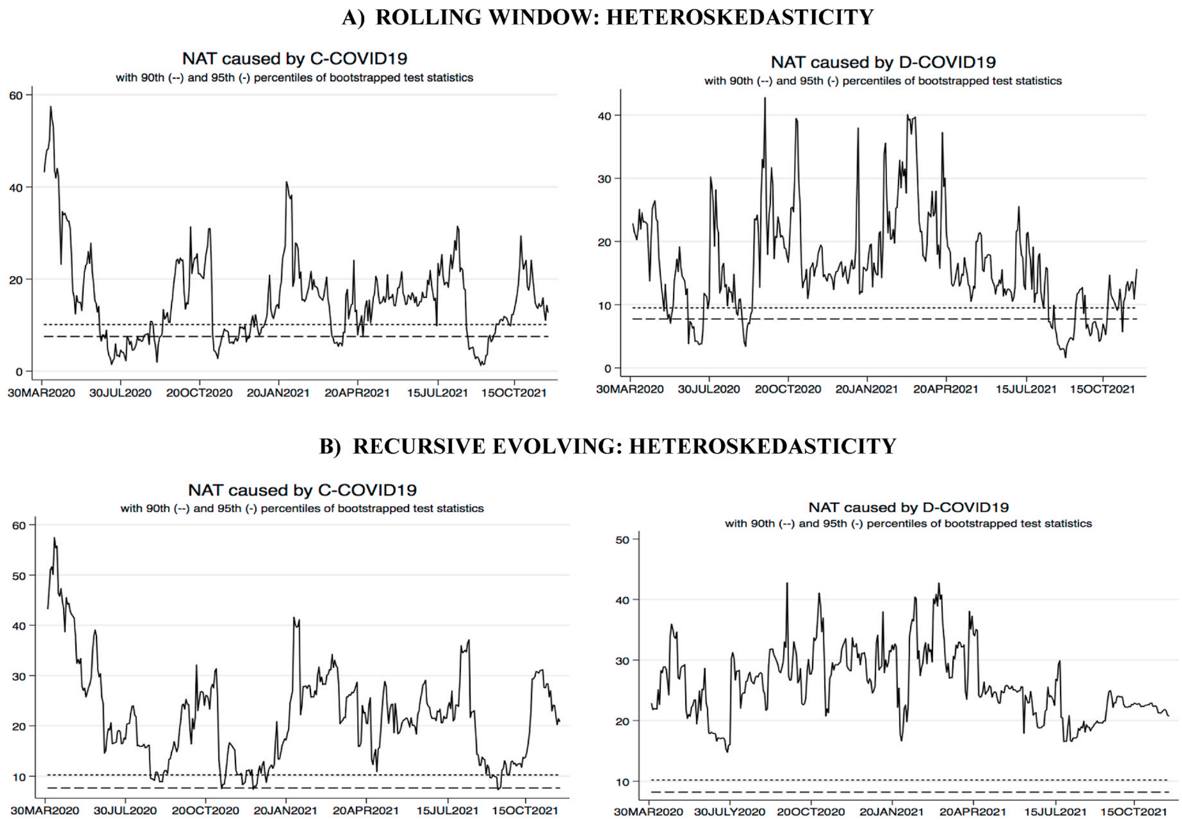

Fig. 6. Granger-causality between natural resources and COVID-19 with heteroskedastic-robust specification.

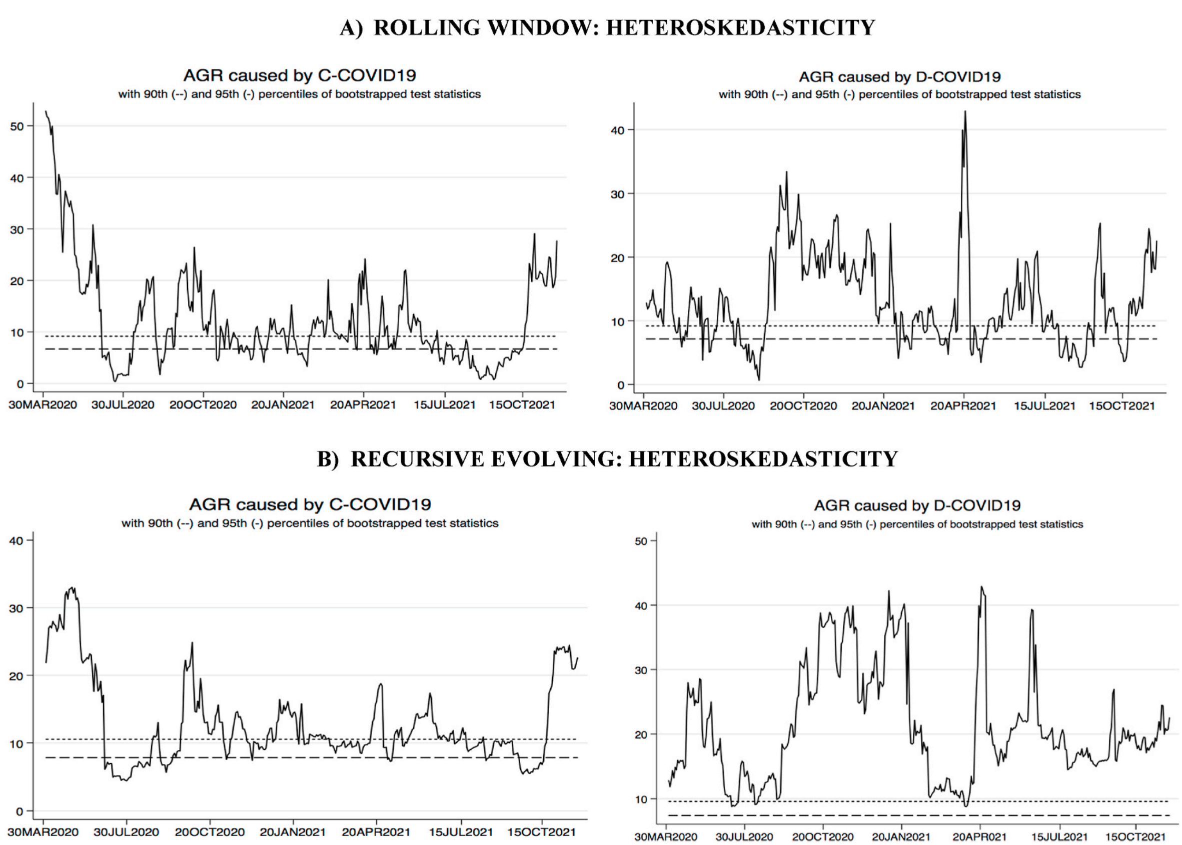

Fig. 7. Granger-causality between agriculture and COVID-19 with heteroskedastic-robust specification.

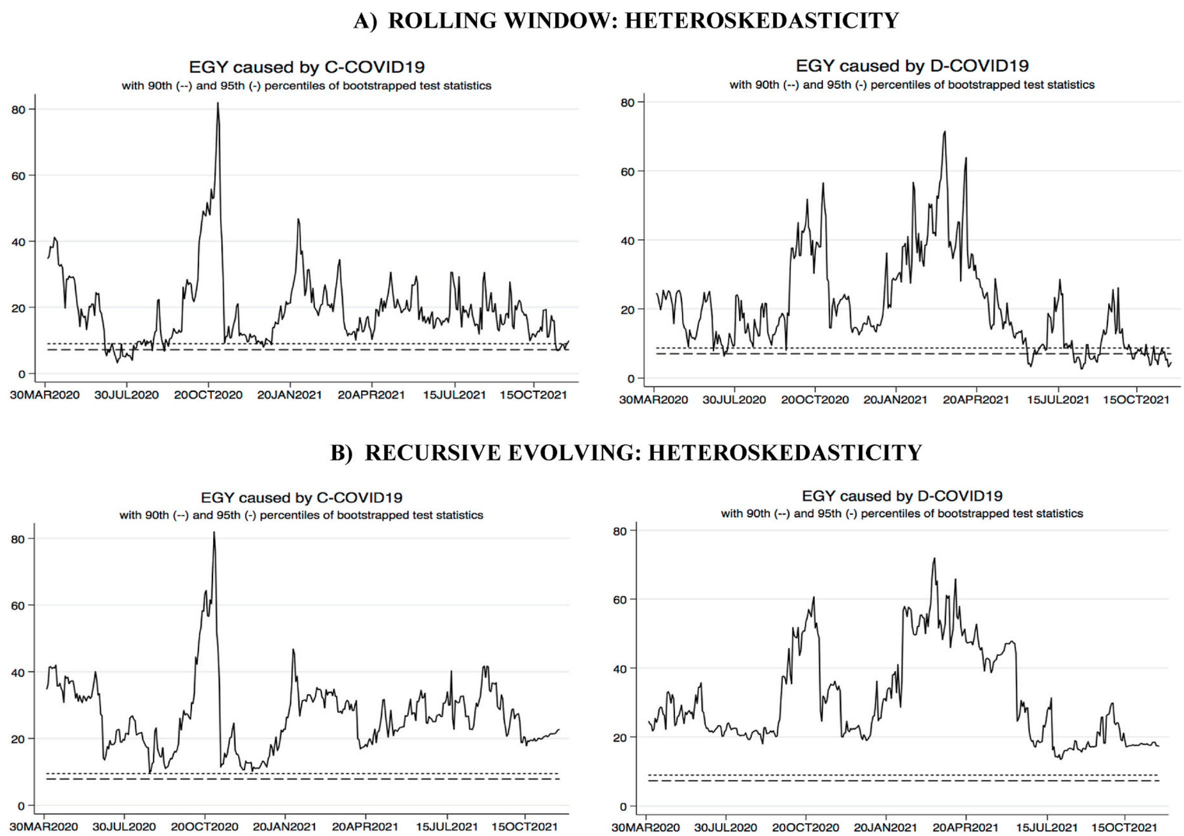

Fig. 8. Granger-causality between energy and COVID-19 with heteroskedastic-robust specification.

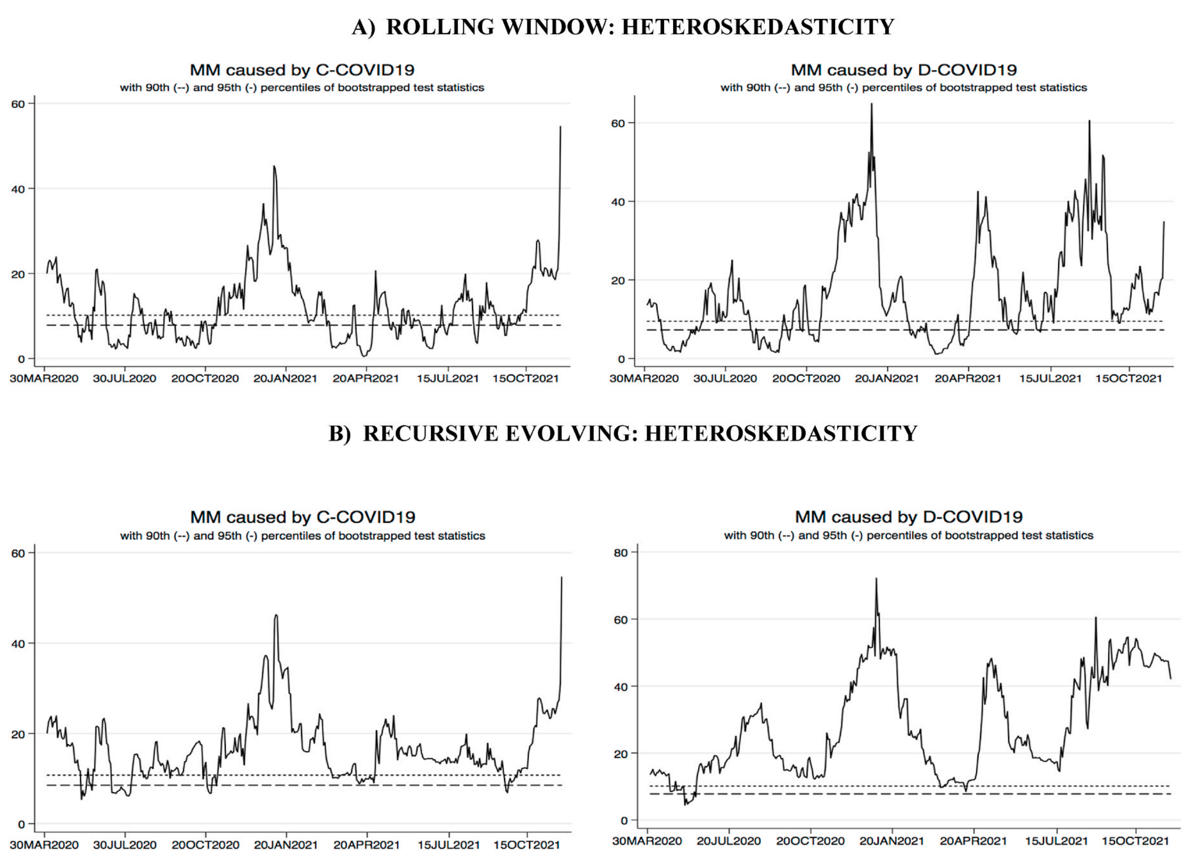

Fig. 9. Granger-causality between metal & mining and COVID19 with heteroskedastic-robust specification.

rolling window in both panels (left and right) shows that the heteroskedastic robust test statistics sequence is volatile over the period supporting time-varying causal linkages. The recursive evolving procedure also depicts, the test statistics (heteroskedastic robust) sequence to be above the critical value sequence for most of the period for C-COVID19 and MM (with few periods below the critical value suggesting time-varying causality) relationships while above the whole sample period for D-COVID19 and MM causality. Thus, MM is Granger caused by C-COVID19 and D-COVID19. Thus, our findings are robust as supported by heteroskedastic specification.

6. Conclusions

The emergence of COVID19 as the pandemic affected all economies around the world. The research studies are flourishing all over the world to develop the linkages between the pandemic and its impact on numerous, however, no previous attempts have been made to examine how natural resources are affected by the pandemic. This study investigated the causal linkages between the pandemic, and natural resources, agriculture, energy, and metal and mining by applying the novel time varying Graner causality test proposed by Shi et al. (2018, 2020) on the daily data from January 23, 2020 to November 12, 2021. The results validate the existence of time-varying Granger causality from C-COVID19 and D-COVID19 to NAT, AGR, EGY, and MM. The results obtained from the rolling window algorithm support causal linkages between the variables however at several points it fails to capture the dynamics of linkages between the variables which is captured by the recursive window algorithm. Furthermore, the duration of linkages suggested by the recursive algorithm is longer when compared to the rolling window procedure. Similarly, the findings obtained from heteroskedastic-robust specification also validate our findings. NAT, AGR, EGY, and MM are Granger caused by C-COVID19 and D-COVID19.

In sum, the pandemic (cases and death) has significantly contributed to natural resources commodities indices by influencing prices and volatilities in the stock and commodity market. The pandemic resulted in higher uncertainty and changed the relationship between the commodities, affected prices, affected demand and supply. Such outcomes created uncertainty in the returns of companies and made investors risk averse. In the light of the above findings, it is suggested that the national governments need to focus on resilient supply chains and automation of the process including NAT, AGR, EGY, and MM, avoiding supply chain failures as well as helping economies in the case of prospective pandemics and natural calamities. Automation and innovation can lead to a decline in labor services, thereby restricting spread. Furthermore, investment in information and communication technology infrastructures can help to alleviate the influence of future pandemic shocks. Particularly, the digitization of maritime can support the effective management of supply chain issues.

The findings of the present study are important for the outcomes associated with natural resources, as policymakers and investors can opt for time-related adjustments and use dynamic and heterogenous strategies, considering the evidence of changing relationships predicted by Granger causality. Since policies associated with the pandemic require time to time revision, depending upon the dynamic evolution of its intensity and diverse effects, the time-varying methodology is the appropriate methodology under such a situation. Particularly, natural resource development matters for resource-dependent economies, an understanding of the time-varying connectivity of the pandemic with natural resources (NAT, AGR, EGY, and MM) provides better management of the natural resource economy. This information can be used by investors for the diversification of their portfolios and time-based adjustment, and government can initiate relevant policies to reduce the effect of the pandemic on the economy. The prices and volatilities can guide the economies involved in the commodity sector to change production, accordingly, avoid risk in stock markets, ensure the supply of relevant materials and decrease the impact of economic recession.

Credit author statement

Eyup Dogan: writings, model, supervision; **Tariq Majeed**: methodology, writings; **Tania Luni**: introduction, literature review.

Declaration of interests

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

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