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The impact of COVID-19 and non-pharmaceutical interventions on energy returns worldwide

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\section*{ABSTRACT}

The COVID-19 pandemic has caused an unprecedented global economic and social crisis, triggering various interventions by governments across geographic regions. The pandemic is significantly affecting all aspects of life, including the energy sector. In this paper, we investigate the bearing of COVID-19 and non-pharmaceutical interventions on the energy returns across 104 global energy indices in 34 countries over the period 1 January to 1 November 2020. Our analyses show that the daily growth in both confirmed cases and cases of death caused by COVID-19 has significant negative direct effects on global energy returns. We also find evidence that various non-pharmaceutical interventions have a significant impact on global energy returns. More specifically, we find that workplace closure and restrictions on internal movement have a positive and significant impact on global energy returns. In contrast, cancellation of public events, closing down public transport, and public information campaigns have a negative and significant impact on them. School closures and international travel controls are, however, negative but insignificant. For energy security, the cornerstone of every economy, our results support the argument for the urgent need for massive investment in the energy sector to boost economic activities, create sustainable jobs, and ensure the resilience of the economies hit by the pandemic.

\section{Introduction}

The coronavirus (COVID-19) pandemic has precipitated one of the greatest global health crises since the Spanish-flu outbreak in 1918. Governments’ sweeping decisions to enforce partial or complete lockdowns, hence shutting down the engine of their respective economies, has resulted in a sharp drop in GDP. In the attempt to save human life, government non-pharmaceutical actions have profoundly impacted livelihoods, with massive job losses across all sectors around the globe.

The energy sector is no exception. The World Bank estimates that under the pandemic, global GDP may be reduced by about 5.2 percent in 2020, resulting in 300 million job losses during the second quarter of 2020. According to the World Bank estimate, the pandemic has the heaviest effect on energy prices, and its effect is expected to continue in 2021 (\textit{World Bank, October 2020}). The volatility in commodity prices and artificially suppressed demand for energy will weaken the financial health of many energy companies, and adversely affect their investment plans. The energy investment is estimated to shrink by an unprecedented level of 20 percent during the current year. It is also estimated that about 8 percent of the 40 million jobs provided by this sector have been lost or put at risk. The restrictions imposed by various governments have resulted in a shock to both supply and demand sides. The deliberate restraints on economic activities are resulting in constraining the overall capacity on the supply side. The fall in corporate investment activities and the pandemic’s impact on the disposable income of consumers results in the demand-side shock. According to the estimates of the International Energy Agency (\textit{IEA, April 2020}), by mid-April, countries under full or partial lockdown would be facing a depression in energy demand of 25 percent and 18 percent, respectively. IEA has also estimated that the global demand for coal in the first quarter of 2020 fell by about 8 percent compared with the first quarter of 2019; electricity demand fell by at least 20 percent, oil demand by 5 percent, and gas demand 2 percent. Full lockdowns have reduced daily demand for electricity by about 15 percent in India, France, Italy, Spain, the UK, and the northwest USA. It is estimated that the share of energy usage in countries under full or partial lockdown spiked from 5 to 52 percent

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between mid-March and the end of April. Driven by larger installed capacity, the growth in the demand for renewable energy was an exception during the first quarter.

IEA estimates that energy demand will contract by 6 percent, the most severe fall during the last 70 years. Moreover, the Institute predicts a 9 percent dip in oil demand down to a level of 9 mb/d, the figure for oil consumption in 2012. As a result of the collapse of global aviation activity, it is estimated that the demand for jet fuel has fallen by 14 percent relative to February 2019. The demand is estimated to have fallen by about 27 percent in March 2020 alone, after the wide implementation of travel bans and the grounding of aircraft fleets (IEA, April 2020). According to the International Air Travel Association, the average capacity utilisation in flights fell to 65 percent of the 2019 level. The flight capacity utilisation is expected to average 40 percent and 10 percent respectively in Q3 and Q4 2020, compared to 2019 (UNCTAD, July 2020). The postponement of large international events like the Tokyo Olympics, and the likely continuation of the containment measures, the gasoline demand is expected to decline by about 11 percent for the whole year 2020. The same set of factors has affected the demand for the consumption of diesel fuel, widely used in trucks and ships for the transportation of goods. The pandemic containment measures have also reduced demand for other products like LPG, naptha, ethane, and residual fuel. The large drop in the oil demand has resulted in extreme price volatility, which has hit the key producers and many oil companies (IEA, June 2020).

The full and partial lockdown measures have significantly reduced the demand for electricity, which has affected the power mix. According to the IEA estimates, based on data from 30 countries representing about one-third of the global electricity demand, indicate that on average, the monthly demand for electricity for industrial and commercial operations fell by 20 percent, representing over 1.5 percent on an annual basis. On an overall basis, it is expected to fall by 5 percent, with some regions recording a dip of 10 percent. There are cascading effects of these falls on the various energy indices worldwide. The electricity distribution companies are hurt by failure in the payment of bills by end-consumers in both the household and industrial sectors. In turn, this has affected the distributors’ ability to pay their dues to the power producers. The significant drop in energy demand has resulted in a collapse of the electricity market price, which has further hurt the power generation companies. The lockdown has also impacted the supply chains of the power sector. The combined effect of these developments is the suspension of non-critical investments throughout the sector from power generation to transmission (IEA, June 2020).

Many studies have already been reported in the literature on the impact of COVID-19 and government interventions on stock market returns (Al-Awdadi, Alsafi, Al-awdadi, & Alhamadi, 2020; Ali, Alam, Aun, & Rizvi, 2020; Ashraf, 2020; Goodell, 2020; Narayan, Phan, & Liu, 2020; Papadamou, Fassas, Kenourgios, & Dimitriou, 2020; Zaremba, Kizys, Aharon, & Demir, 2020; Zhang, Hu, & Ji, 2020). However, none has analysed the effect of COVID-19 and non-pharmaceutical interventions by governments on the energy indices. Our paper aims to bridge this gap by investigating the impact of both COVID-19 and non-pharmaceutical interventions on returns in the energy sector worldwide. Using the available daily number of COVID-19 cases and deaths and energy returns data for 104 energy indices from 34 countries over the period January 1 to November 1, we examine the impact of the growth in COVID-19 confirmed cases and deaths and the non-pharmaceutical interventions on energy returns, after controlling for country characteristics.

Zaremba et al. (2020) argue that non-pharmaceutical government interventions such as public information campaigns and the cancellation of public events to contain the spread of COVID-19 are significant; governments should recognise that apart from the adverse effect on the economy, related restrictions have a discernible effect on the trading activities of the financial markets. Vayanos (2004) finds that in periods of stress and heightened volatility in markets, investment managers fear redemptions resulting in ‘flight to liquidity’. This phenomenon was termed ‘flight to quality’ or ‘flight to safety’ (FTS) by Caballero and Krishnamurthy (2008). Baele, Bekker, Inghelbrecht, and Wei (2020) note that during episodes of FTS, there are sharp decreases in commodity prices. Non-pharmaceutical interventions to contain the effects of COVID-19 may affect volatility in energy returns through two principal channels. The first is the ‘rational’ channel, which relates to portfolio restructuring. The interventions signal uncertainties in future economic conditions that affect the cash-flow expectations of the energy corporations and, in turn, their stock prices. The resulting abrupt portfolio re-constructions—both within an asset class and across asset classes—may heighten the volatility in energy returns. The second channel, which may be termed ‘irrational’, arises from investors’ behaviour. The prospect of deterioration in national economic conditions may trigger FTS (Baele et al., 2020), resulting in rapid portfolio flows and consequent changes in the energy indices. The constant flow of policy-related news in various media may lead to news-implied volatility (Manela & Moreira, 2017), causing potential divergence of opinions precipitating increased trading activity (Banerjee, 2011) and further attenuating volatility in the market (Foucault, Sraer, & Thesmar, 2011).

Our study contributes to the literature in several ways. First, it adds to the body of knowledge addressing how financial markets react to exogenous events such as news (Li, 2018), the environment (Goo, Kuai, & Liu, 2020), disasters (Kowalewski & Spiewanowski, 2017), and the outbreak of potential pandemics such as Spanish Flu (Barro, Ursúa, & Weng, 2020), Ebola Virus Disease (EVD) (Ichev & Marinci, 2018) and Severe Acute Respiratory Syndrome (SARS) (Chen, (Shawn) Jang, & Kim, 2007). Second, our study adds to recent publications on the effects of COVID-19 on economic activity (Baker, Bloom, Davis, & Terry, 2020; Eichenbaum, Rebelo, & Trabandt, 2020), and on financial markets (Al-Awdadi et al., 2020; Ali et al., 2020; Ashraf, 2020; Goodell, 2020; Papadamou et al., 2020; Zaremba et al., 2020; Zhang et al., 2020), which note that the ‘new cases’ reported in and outside China have a mixed effect on financial volatility, while the ‘deaths’ reported outside China have triggered a more powerful reaction (Albulescu, 2020) in financial volatility. Third, in this paper, we expand the scope of the literature by looking at the impact of COVID-19 on returns of 104 energy sectors in 34 countries and examining the effect of non-pharmaceutical interventions on energy returns worldwide. To our knowledge, this study is the first to examine this topic. Fourth, this study is the first to introduce into the analytical framework the daily growth in both the total and the newly confirmed cases and the daily growth in both total and new deaths caused by COVID-19. We also use different definitions of the confirmed cases and deaths to assess the robustness of the results. We use seven non-pharmaceutical interventions: school closures, workplace closures, cancellation of public events, closing down public transport, public information campaigns, restrictions on internal movement, and international travel controls. Fifth, our evaluation of the effect of COVID-19 and non-pharmaceutical interventions on energy returns will help governments not only in modulating their fiscal spending but also in enabling them to regulate their markets better and monitor the financial health. Sixth, this study introduces the price volatility of West Texas Intermediate (WTI) crude oil price and Brent crude oil price as a systemic variable into the analytical framework. Finally, we consider the dynamic nature of the data on COVID-19 (the number of deaths and the number of confirmed cases). We also consider the possible non-linearity of the effects.

Using time-series data, the results of our analyses show that the daily growth in both newly confirmed cases and cases of death caused by COVID-19 has significant negative direct effects on global energy returns. Similar results are found when we use the daily growth in total confirmed cases and total cases of death caused by COVID-19. We also find evidence that the various non-pharmaceutical interventions have a significant impact on global energy returns. More specifically, we find that workplace closures and restrictions on internal movement have a
positive and significant impact on global energy returns, while the cancellation of public events, closing down public transport, and public information campaigns have a negative and significant impact on global energy returns. School closures and international travel controls are, however, negative but insignificant.

The remainder of the article is as follows. Section 2 describes our data and methods. Section 3 reports the results of empirical analyses. Section 4 concludes the study.

2. Data and methodology

2.1. Data

As shown in Table 1, our paper is based on 104 energy indices from 34 countries covered by the Bloomberg database. Our sample period runs from 1 January to 1 November 2020 for the benchmark indices: the 104 energy indices in 34 countries. Our empirical model for modelling energy returns for the 104 energy indices includes the daily absolute change in the energy return index of a sector as modelled by Antona-Kakis & Kizys (2015; Ashraf, 2020; Khalifa, Miao, & Ramchander, 2011; Zaremba et al., 2020). COVID-19 denotes the daily growth in the number of COVID-19 infections (cases) or deaths. OilPrice is the daily change in Brent and WTI crude oil price indicators. NonPharmaceuticalInterventions is the various non-pharmaceutical interventions for the country. We use seven different types of non-pharmaceutical intervention targets to curb the pandemic: school closures, workplace closures, cancellation of public events, closing down of public transport, public information campaigns, restrictions on internal movement, and international travel controls (Hale et al., 2020). The indices of school closures and workplace closures have a scale of 0–3. The indices of cancellation of public events, closing down of public transport, public information campaigns, and the restrictions on internal movement have a scale of 0–2. While the international travel controls index has a scale of 0–4, where 3, 2, and 4 in respective scales represent maximum values of the corresponding

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\text{EnergyReturn}_{it} = \beta_0 + \beta_1 \text{EnergyReturn}_{it-1} + \beta_2 \text{COVID} - 19_{it-1} + \beta_3 \text{OilPrice}_i + \\
\sum_{j=1}^{J} \beta_j \text{NonPharmaceuticalInterventions}_j + \\
\sum_{j=1}^{J} \phi_j \text{DailyDummy}_j + \epsilon_{it}
\]
In our baseline approach, we consider all the government actions, regardless of whether they were country-wide or targeted at certain regions. For the Johansen panel cointegration test, the assumption of cointegration tests allows for individual effects but no individual linear trends in vector autoregressive models. The null hypothesis of no cointegration is rejected at the 0.01 level (results available on request).

In the first stage, we examine the effect only of COVID-19 on global energy returns, and then we investigate the effect of both COVID-19 and non-pharmaceutical interventions on these returns. Our estimation results in Table 4 indicate that both daily growth in total confirmed cases and daily growth in total confirmed COVID-19 deaths have a significant and negative impact on the energy returns at 1 % (Models 1 and 2). Similar results are found when we re-run the models with daily growth in newly confirmed cases and daily growth in newly confirmed deaths (Models 3 and 4). We find similar results when

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2 ControlVariables comprises control variables, including the natural logarithm of daily market capitalization, and the daily market-to-book ratio of energy firms. DailyDummy is a set of daily fixed-effects dummies, included to control for daily international events that move all markets. \( \epsilon \) is the error term. The definitions of all variables used in this study and their sources are presented in Appendix A. The regression is estimated using OLS, and the p-values are corrected for standard errors that are robust to heteroskedasticity and autocorrelation. We control for the unobserved time-constant heterogeneity at the daily level by including daily individual dummies and then employ pooled OLS to estimate the model with the one-day lag of the dependent variable as a covariate.

3 Control variables refer to the two major types of energy companies: non-renewable energy companies (oil and petroleum products, gasoline, natural gas, and diesel fuel) and renewable energy companies (hydropower, solar power, and wind power).
we add Brent crude oil prices and country-level control variables (Models 5–8). We also find similar results when we repeat our analysis with or without daily fixed-effects dummy variables (results are available on request).

In the overall analysis, these results indicate that the energy sector responds negatively and overwhelmingly to growth in both confirmed COVID-19 cases and related deaths. This strongly confirms the proposition that energy investors price the expected negative impact of COVID-19 according to the growth in both confirmed cases and deaths. Our results are in line with Al-Awadhi et al. (2020), who find that stock markets react with negative sentiments to the number of confirmed cases and deaths.

Interestingly, our results are robust under alternative model specifications and regression forms. The main overall results remain virtually the same when we use alternative control variables representing COVID-19 development, such as the natural logarithm of the daily confirmed total number of cases and deaths. This approach also indicates a negative and significant effect on energy returns. Furthermore, our results remain similar even when we re-run the model including daily confirmed new COVID-19 cases and deaths in one model (results are available on request).

Of the oil price, we find the estimated coefficient on the Brent oil price is positive and statistically significant at the 1% level, supporting the argument that increases in oil prices strengthen the energy sector’s return. This finding indicates that a higher oil price is related to higher market liquidity, which is then intermediated into investing, resulting in increased energy returns.

In the next stage we assess the effect of both COVID-19 and non-pharmaceutical interventions on energy sector returns and report the results in Table 5. All columns in this table show that both daily growth in total and newly confirmed cases and daily growth in total and newly confirmed COVID-19 deaths have a significant and negative impact on the global energy returns at 1% (Models 1–8), similar to the results reported in Table 4. This confirms that the energy sector responds negatively and crushingly to growth in both confirmed COVID-19 cases and deaths.

Regarding the effect of non-pharmaceutical interventions on energy returns, our analysis has mixed results. As shown in Table 5, Models 1–4 indicate that workplace closure and restrictions on internal movement have a positive and significant impact on global energy returns at the 1% level. However, we find cancellation of public events, closing down of public transport, and public information campaigns have a negative and significant impact on global energy returns at the level of 1%. School closures and international travel controls are negative but insignificant. More specifically, a one-point increase in the index of workplace closure and restrictions on internal movement increases average daily global energy market returns by 2.97% and 3.45%, respectively. A one-point increase in the index of the cancellation of public events, closing public transport, and public information campaigns reduces average daily global energy market returns by 3.11%, 3.51, and 6.25%, respectively. These results are robust even when we add control variables with daily fixed-effects dummy variables (Models 5–8).4

The positive effect of workplace closure and restrictions on internal

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4 The results are also robust even when we add control variables without daily fixed-effects dummy variables (results are available from authors on request).
movement can be explained by the fact that these government interventions to stall the pandemic’s progress boost public confidence, resulting in a positive impact on energy indices. IEA estimated that at the height of lockdowns, the time spent at home increased by nearly 30 percent and was 5–10 percent higher in June and October 2020 resulting in a significant and complex shift in energy demand. It has been estimated that a day of working from home increase household’s consumption of energy by 7–23 percent in comparison with a day working at the office. In the US, the usage of electricity on weekdays went up by nearly 20–30 percent during the peak of lockdown, and the said figure was 40 percent in the European economies (IEA, December 2020). However, the negative impact of the cancellation of public events, closing down public transport, and public information campaigns may be interpreted as restrictive and give rise to fear of the unknown, hence negatively affecting energy indices. Financial investors may perceive such interventions as a negative signal and a precursor to further intervention, resulting in economic and financial instability across the globe. It is relevant to refer to some recent studies on pandemic-induced stock price volatility in the global stock market. Baele et al. (2020) argue that the gloomy macro-economic environment may trigger price volatility and large portfolio flows resulting from “flight to safety”. Manela and Moreira (2017) find that there is increased news-induced volatility and opinion divergence due to a continuous flow of policy-related news, resulting in increased trading in the stock market (Banerjee, 2011; Harris & Raviv, 1993) and adds further to the volatility.

In sum, non-pharmaceutical interventions through workplace closure and restrictions on internal movement aimed at curbing the COVID-19 pandemic are beneficial to global energy stock market turnover. However, government non-pharmaceutical interventions through the cancellation of public events, closing of public transport, and public information campaigns are not only unhelpful but also strongly negatively affect the global energy stock market turnover. What can be said is that workplace closure and restrictions on internal movement may motivate investors to restructure their portfolio positions, facilitating additional trading in the market. Thus, turnover remains at a higher level as long as investors anticipate that these stringent interventions will continue. On the other hand, the cancellation of public events, closing down public transport, and public information campaigns spread fear, which adversely affects the movement of energy indices.

4. Robustness tests

In this section, we perform several robustness tests to confirm our main results further. First, we re-estimate all the specifications of Table 5 with control country effects as well as with cluster standard errors at the country level. In the reported results in Table 6, we observe that all results are quite similar to the main results that reported in Table 5.

Third, we also collect the daily data of individual energy firms and adopt various alternative econometric methodologies for estimations, to address certain econometric concerns such as country, firm, and daily
fixed effects, endogeneity issues, and non-standard error terms.\textsuperscript{5} The results are reported in Table 8. We use two-stage least squares (2SLS) estimation.

\textsuperscript{5} We use panel data analysis techniques (2SLS, Driscoll-Kraay standard errors, and system GMM estimators) over the classical event study methodology due to several reasons: First, the spread of COVID-19 evolves over a matter of days in a country and is not a one-off event. Second, panel data regression is better in capturing the time varying relationship between dependent and independent variables (Ashraf, 2020). Third, panel data analysis extracts both cross-sectional and time series variation from the underlying panel data and minimizes the problems such as multicollinearity, heteroscedasticity and estimation bias (Wooldridge, 2010). In addition, because of the dynamic nature of the returns of stock markets and economic behaviour, we employ the 2SLS and GMM estimators to estimate the joint effects of COVID-19 and non-pharmaceutical interventions on energy returns. Another important challenge is the unobservable heterogeneity across stock markets, which is difficult to measure. This heterogeneity could be substantial across economies. Finally, because of political interference, there could be a problem with the persistence of returns across various economies. We use the 2SLS and GMM estimator to tackle these problems together. Papadamou et al. (2020) confirm that the GMM estimation allows assessing the relationships between return and volatility in the stock market and between COVID-19 and stock market variables. The system GMM performs better than the difference GMM since it is more robust in reducing the finite sample bias and improving the efficiency gains. It also deals with serial correlation better than the difference GMM. Moreover, it addresses the problem of unit root property and gives more accurate results (Bond, 2002). In addition, Windmeijer (2005) argues that the two-step system GMM estimator is more robust to the problem of weak instruments and is therefore more efficient than the one-step version due to lower bias and standard errors. Given these reasons, in our analysis we also employ the two-step system GMM estimator with Windmeijer (2005) corrected standard error. We use the Hansen test of over-identifying restrictions and the Arellano-Bond test for autocorrelation to test the instrument’s validity.

instrumental variable estimator because our empirical model may raise potential endogeneity concern. We also use Driscoll-Kraay standard errors (Driscoll & Kraay, 1998), which is robust not only to the heteroscedasticity and serial correlation of the error terms within firms but also the correlation between firms.\textsuperscript{6} In addition, we use the system generalized method of moments (GMM) estimator to address the endogeneity issues. System GMM provides an endogeneity test for the other firm-specific variables as well. The second advantage of system GMM is that we can model energy firm return as dynamic as it might be persistent over time due to inter-temporal returns smoothing, competition, regulations or relationship with risky customers. Finally, system GMM exploits not only the time-series but also the cross-sectional dimension of our dataset. Overall, therefore, 2SLS, Driscoll-Kraay standard errors, and system GMM estimators provide another way to test the robustness of our results. The results of estimations using the 2SLS, Driscoll-Kraay standard errors, and system GMM estimators are presented in Table 8 and show that the main results remain unchanged.

Fourth, to further assess the robustness of our results, we use daily data of individual energy firms and follow Antonakakis and Kizys (2015), Khalifa et al. (2011), and Zaremba et al. (2020) and use another five different measures tracking day-to-day changes in energy return. The first measure is the logarithm of absolute return. The logarithmic transformation ensures that the volatility measure in levels is positive definite. It also accounts for the fact that the relationship between the level of volatility and its covariates is not necessarily linear. The remaining four measures are logarithms of absolute residual returns. The error terms may be correlated between energy firms since firms located in the same country might encounter a country-wide unobserved shock, or even a globe-wide one, thus causing the change in firms’ return inter-correlated.

\textsuperscript{6} The error terms may be correlated between energy firms since firms located in the same country might encounter a country-wide unobserved shock, or even a globe-wide one, thus causing the change in firms’ return inter-correlated.
from four different asset pricing models: the Capital Asset Pricing Model (CAPM) by Sharpe (1964), the Fama and French (1993) three-factor model (FF), the Asness, Moskowitz, and Pedersen (2013) three-factor model (AMP), and the Carhart (1997) four-factor model (CAR). As shown in Table 9, we observe that all results are quite similar to that in Tables 4 and 5.

5. Conclusions and discussion

In this paper, we examine the effect of COVID-19 and non-pharmaceutical interventions on energy returns across the globe. We use daily COVID-19 total and newly confirmed cases and deaths and energy return data for 104 energy indices from 34 countries from 1 January to 1 November 2020.

Using time-series data, we find that both the daily growth in the total numbers of confirmed cases and cases of death caused by COVID-19 have a significant negative direct effect on global energy returns. Similar results are found when we use the daily growth in newly confirmed cases and new deaths caused by COVID-19. Energy returns decline as national numbers of both confirmed cases and deaths increase. We also find evidence that the various non-pharmaceutical interventions have a significant impact on global energy returns. More specifically, we find that workplace closures and restrictions on internal movement have a positive and significant impact on global energy returns, while cancelling public events, closing public transport, and public information campaigns have a negative and significant impact on these returns. School closures and international travel controls are, however, negative but insignificant.

According to the World Bank (Jan 2021), there are uncertainties in the prospects for growth of the global economy. The global GDP is expected to rise 4 percent in 2021 based on proper management of the pandemic and effective vaccination to limit the spread of Covid-19 in many countries as well as the accommodative stance of monetary policy and diminishing fiscal support. It is argued by IEA that there is an urgent need for massive investment in the energy sector to boost economic activity, sustainability and resilience of the economies concerned (IEA, July 2020). Being long-term in nature, investment decisions in the energy sector will also have long-term implications for how energy is produced and consumed, and hence must be aligned with the national objectives of governments. According to IEA the progress of energy efficiency faces further setbacks due to the pandemic. Investment in efficiency is projected to fall by 9 percent in 2020. Investments in new energy-efficient buildings (Mehdagh & Ghoneim, 2020; Rodrigues & Freire, 2021; Sarihi, Saradj, & Faizi, 2020; Shokouhyar, Shokoohyar, Sobhani, and Gorizi et al., 2021), equipment and vehicles are expected to decline in 2020 adversely affecting the IEA’s sustainable development scenario of reducing greenhouse gas emissions in the next 20 years. The stimulus packages announced by governments to counter the pandemic effect, however, provide some hope (Hepburn, O’Callaghan, Stern, Stiglitz, & Zenghelis, 2020). Of the US$66 billion funding for energy

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The corresponding regression models are represented by the following five equations, respectively: $	ext{EnergyReturn}_t = \log\left(\text{EnergyReturn}_t\right)$ (1). $\text{EnergyReturn}_t = \beta_0 + \beta_1 \text{MKT}_t + \beta_2 \text{SMB}_t + \beta_3 \text{HML}_t + \epsilon_t$ (2). $\text{EnergyReturn}_t = \beta_0 + \beta_1 \text{MKT}_t + \beta_2 \text{SMB}_t + \beta_3 \text{HML}_t + \epsilon_t$ (3). $\text{EnergyReturn}_t = \beta_0 + \beta_1 \text{MKT}_t + \beta_2 \text{HML}_t + \beta_3 \text{WML}_t + \epsilon_t$ (4). $\text{EnergyReturn}_t = \beta_0 + \beta_1 \text{MKT}_t + \beta_2 \text{SMB}_t + \beta_3 \text{HML}_t + \beta_4 \text{WML}_t + \epsilon_t$ (5) where $\text{EnergyReturn}_t$ is the energy excess return on day $t$; $\beta$ is the regression coefficients; $\text{MKT}_t$, $\text{SMB}_t$, $\text{HML}_t$, and $\text{WML}_t$ are daily energy returns on market, small-minus-big, high-minus-low, and winners-minus-losers factors, respectively; and $\epsilon_t$ is the random disturbance terms.
related measures as part of the stimulus packages announced by various governments tracked by IEA, 26 billion and US$20 billion have been allocated to the building sector and shift for commercial vehicles. Managing post-pandemic economic recovery in a sensible manner to ensure the balance between economic prosperity and the consequent positive effect on stock returns and climate protection is therefore a critical challenge (IEA October 2020). IEA (2020a, 2020b, 2020c) has argued that the recovery plans by governments should be aligned with the energy resilience and sustainable development on a long-term basis. The sustainable recovery plan proposed by IEA for the energy sector include delivering shovel-ready clean energy projects to boost resilience and investment in longer term infrastructure and energy efficiency projects. It can be argued that changes as perceived by the sustainable recovery plan would put the energy company returns on a more stable footing. The sustainable recovery plan is expected to trigger the process of a structural reorientation of the energy sectors by fostering the shift of economic activities towards more sustainable and resilient sectors.

Fig. 6. Energy markets volatility -absolute returns during the COVID-19 period (Jan 01 to Nov 09, 2020).

### Table 2

| Variable                        | Mean     | Std. Dev. | Min     | Max     | Skewness | Kurtosis | VIF |
|---------------------------------|----------|-----------|---------|---------|----------|----------|-----|
| Energy returns                  | 0.00     | 0.04      | -0.13   | 0.12    | -0.25    | 6.71      |     |
| Total COVID-19 cases           | 317176.34| 1074296.04| 9971651.00| 1.00 | 2.59    | 8.18      |     |
| New COVID-19 cases             | 3554.26  | 11298.30  | 130623.00| 0.00 | 2.94    | 9.95      |     |
| Total COVID-19 deaths          | 81.75    | 252.23    | 4928.00 | 0.00 | 2.82    | 9.25      |     |
| Δ Total COVID-19 cases         | 5.29     | 23.99     | 1400.00 | 0.00 | 2.94    | 9.95      | 17.04|
| Δ New COVID-19 cases           | 71.39    | 359.42    | 19428.57| 0.00 | 2.55    | 7.87      | 6.96 |
| Δ Total COVID-19 deaths        | 3.92     | 15.81     | 460.00  | 0.00 | 2.82    | 9.25      | 13.32|
| Δ New COVID-19 deaths          | 85.60    | 206.78    | 5166.67 | 0.00 | 2.72    | 8.86      | 6.01 |
| School closures                | 0.96     | 1.36      | 0.00    | 3.00 | 0.77    | 1.66      | 4.73 |
| Workplace closures             | 0.74     | 1.17      | 0.00    | 3.00 | 1.13    | 2.52      | 4.09 |
| Cancelling of public events    | 0.67     | 0.90      | 0.00    | 2.00 | 0.70    | 1.59      | 4.03 |
| Closing down of public transport| 0.29    | 0.56      | 0.00    | 2.00 | 1.83    | 5.29      | 4.92 |
| Public information campaigns   | 1.03     | 0.97      | 0.00    | 2.00 | -0.05   | 1.06      | 4.57 |
| Restrictions on internal movement| 0.54    | 0.83      | 0.00    | 2.00 | 1.04    | 2.26      | 4.45 |
| International travel controls  | 1.54     | 1.59      | 0.00    | 2.00 | 0.25    | 1.34      | 4.38 |
| Brent crude oil prices         | -0.23    | 9.37      | -47.47  | 50.99 | 1.12    | 10.54     | 5.81 |
| WTI crude oil prices           | -0.73    | 20.06     | -301.97 | 53.09 | 0.66    | 6.90      | 5.79 |
| Market capitalization          | 15.11    | 2.92      | 7.87    | 21.54 | -1.91   | 6.02      | 3.35 |
| Market-to-book ratio           | 2.98     | 1.52      | 0.29    | 5.96 | -0.73   | 2.28      | 4.41 |

This table reports the statistical properties of dependent and independent variables used in the study.
Towards electricity and increasing share of low-carbon energy sources. The new revenue streams resulting from the impending structural shift of economic systems away current fossil-fuel intensive (Hepburn et al., 2020) would strengthen the returns in the energy sector.

Our assessment of the effect of COVID-19 and non-pharmaceutical interventions on energy returns will be helpful for governments not only to modulate their fiscal spending but also enable them to regulate their markets better and to monitor the financial health. The integrity of the government and its interventions complemented by stable and reliable investment policy is crucial for the confidence of firms as well as households in times of uncertainty. It fosters the revival of business sentiments that may help firms plan future investments and households in times of uncertainty. It fosters the revival of business sentiments that may help firms plan future investments and households in times of uncertainty.

### Table 4

The effect of COVID-19 on energy sector returns.

|                            | (1)        | (2)        | (3)        | (4)        | (5)        | (6)        | (7)        | (8)        |
|---------------------------|------------|------------|------------|------------|------------|------------|------------|------------|
| Energy returns at-        | -0.413***  | -0.450***  | -0.331***  | -0.381***  | -0.192***  | -0.211***  | -0.165***  | -0.178***  |
|                           | (0.0011)   | (0.0012)   | (0.0024)   | (0.0041)   | (0.0091)   | (0.0095)   | (0.0106)   | (0.0095)   |
| ΔTotal COVID-19 cases     | -0.074***  |            |            |            |            |            |            |            |
|                           | (0.0044)   |            |            |            |            |            |            |            |
| ΔTotal COVID-19 deaths    | -0.018***  | -0.026***  |            |            |            |            | -0.018***  |            |
|                           | (0.009)    | (0.0021)   |            |            |            |            | (0.0031)   |            |
| ΔNew COVID-19 cases       |            |            |            |            |            |            |            | -0.085***  |
|                           |            |            |            |            |            |            |            | (0.0072)   |
| ΔNew COVID-19 deaths      | -0.016***  |            |            |            |            | -0.016***  |            | -0.085***  |
|                           | (0.0003)   |            |            |            |            | (0.0003)   |            | (0.0003)   |
| Crude oil prices          |            |            |            |            | 0.054***   | 0.055***   | 0.056***   | 0.053***   |
|                           |            |            |            |            | (0.0003)   | (0.0003)   | (0.0004)   | (0.0005)   |
| Market capitalization     |            |            |            |            | -0.087***  | -0.081***  | -0.035***  | -0.086***  |
|                           |            |            |            |            | (0.0045)   | (0.0047)   | (0.0059)   | (0.0042)   |
| Market-to-book ratio      |            |            |            |            | -0.041     | -0.008     | -0.072     | 0.044      |
|                           |            |            |            |            | (0.0207)   | (0.0207)   | (0.0581)   | (0.0296)   |
| Daily dummies             | Yes        | Yes        | Yes        | Yes        | Yes        | Yes        | Yes        | Yes        |
| R2                        | 0.348      | 0.327      | 0.388      | 0.350      | 0.419      | 0.488      | 0.456      | 0.434      |
| Pesaran’s test of CD      | 87.18***   | 89.75***   | 0.897***   | 87.76      | 71.71***   | 73.27***   | 73.626***  | 69.77***   |

This table shows the impact of COVID-19 on the volatility of energy returns around the globe using time series estimator. The values in parentheses are standard errors. *, ** and *** denote significance at 10%, 5% and 1% levels, respectively.
Table 5
The effect of COVID-19 and non-pharmaceutical interventions on energy sector returns.

| (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
|-----|-----|-----|-----|-----|-----|-----|-----|
| **L.Energy returns** | 0.052*** | 0.052* | 0.019*** | 0.039*** | -0.164*** | -0.188*** | -0.120*** | -0.158*** |
| (0.0053) | (0.0052) | (0.0052) | (0.0053) | (0.0100) | (0.0114) | (0.0114) | (0.0101) |
| **ΔTotal COVID-19 cases** | -0.065*** | -0.065*** | -0.041*** | -0.076*** |
| (0.0052) | (0.0052) | (0.0116) | (0.0116) |
| **ΔNew COVID-19 deaths** | -0.013*** | -0.017*** | -0.022*** |
| (0.0011) | (0.0022) | (0.0086) |
| **ΔNew COVID-19 deaths** | -0.003 | -0.003 | -0.003 | -0.003 | -0.003 | -0.003 | -0.003 | -0.003 |
| **Market-to-book ratio** | 0.027** | 0.027** | 0.027** | 0.027** |
| (0.0064) | (0.0064) | (0.0064) | (0.0064) |
| **Market capitalization** | 0.091*** | 0.091*** | 0.091*** | 0.091*** |
| (0.0177) | (0.0177) | (0.0177) | (0.0177) |
| **Market-to-book ratio** | -0.052*** | -0.052*** | -0.052*** | -0.052*** |
| (0.0014) | (0.0014) | (0.0014) | (0.0014) |
| **Daily dummies** | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| **Pesaran’s test of CD** | 83.71*** | 84.05*** | 84.04*** | 80.58*** | 69.26*** | 69.28*** | 69.47*** | 65.35*** |

This table shows the impact of COVID-19 and non-pharmaceutical interventions on the volatility of energy returns around the globe. The values in parentheses are standard errors. *, ** and *** denote significance at 10%, 5% and 1% levels, respectively.

Table 6
The effect of COVID-19 and non-pharmaceutical interventions on energy sector returns: controlling country effects and cluster standard errors (robustness check 1).

| Panel A: Control country effects | Panel B: Cluster standard errors at country level |
|--------------------------------|-----------------------------------------------|
| (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
| **L.Energy returns** | -0.148*** | -0.149*** | -0.145*** | -0.148*** | -0.148*** | -0.149*** | -0.145*** | -0.148*** |
| **Δ Total COVID-19 cases** | -0.074*** | -0.074*** | -0.054*** | -0.067*** | -0.058*** | -0.069*** | -0.054*** |
| **Δ New COVID-19 deaths** | -0.078 | -0.078 | -0.074 | -0.087 | -0.078 | -0.085 | -0.074 | -0.087 |
| **School closing** | 0.073*** | 0.072*** | 0.076*** | 0.072*** | 0.073*** | 0.073*** | 0.079*** | 0.078*** |
| **Workplace closure** | -0.012*** | -0.014** | -0.092*** | -0.015** | -0.012*** | -0.014*** | -0.092*** | -0.015** |
| **Cancelling of public events** | -0.063*** | -0.061** | -0.057*** | -0.056** | -0.061*** | -0.061** | -0.058*** | -0.056** |
| **Restrictions of internal movement** | -0.027*** | -0.029*** | -0.026*** | -0.029*** | -0.028* | -0.029* | -0.026* | -0.029* |
| **Public information campaigns** | 0.028** | 0.026* | 0.036** | 0.024* | 0.028* | 0.026* | 0.036* | 0.024* |
| **Market capitalization** | -0.015 | -0.016 | -0.017 | -0.016 | -0.018 | -0.015 | -0.015 | -0.016 |
| **Market-to-book ratio** | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| **Country dummies** | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |

This table shows the impact of COVID-19 and non-pharmaceutical interventions on the volatility of energy returns around the globe. Standard errors are not displayed. *, ** and *** denote significance at 10%, 5% and 1% levels, respectively.
### Table 7

The effect of COVID-19 and government non-pharmaceutical interventions on energy sector returns: various scenarios (robustness check 2).

| Entry of the non-pharmaceutical interventions’ variables one at a time | Stepwise entry of the non-pharmaceutical interventions’ variables |
|------------------------------------------------|--------------------------------------------------|
| (1) (2) (3) (4) (5) (6) (7) | (8) (9) (10) (11) (12) (13) |
| **Panel A: Without control variables** |
| L.Energy returns | 0.111*** |
| School closing | 0.034 |
| Workplace closing | 0.037*** |
| Cancelling of public events | 0.027*** |
| Closing of public transportation | 0.039** |
| Restrictions of internal movement | -0.015** |
| International travel controls | 0.059*** |
| COVID-19 cases/deaths | No |
| Control variables | No |
| Daily dummies | No |
| Country dummies | No |
| **Panel B: With control variables** |
| L.Energy returns | -0.068** |
| Δ Total COVID-19 cases | -0.094*** |
| School closing | 0.035 |
| Workplace closing | 0.043*** |
| Cancelling of public events | 0.029** |
| Closing of public transportation | -0.018** |
| Public information campaigns | -0.012** |
| Restrictions of internal movement | 0.054*** |
| International travel controls | 0.035 |
| Brent crude oil prices | 0.019*** |
| Market capitalization | -0.086** |
| Market-to-book ratio | 0.039 |
| Daily dummies | Yes |
| Country dummies | Yes |

This table shows the impact of COVID-19 and non-pharmaceutical interventions on the volatility of energy returns around the globe. Standard errors are not displayed. *, ** and *** denote significance at 10%, 5% and 1% levels, respectively.
Table 8
The effect of COVID-19 and government non-pharmaceutical interventions on energy sector returns: Alternative econometric specifications (robustness check 3).

|                          | Panel A: 2SLS | Panel B: Driscoll-Kraay standard errors | Panel C: Tow-step System GMM |
|--------------------------|--------------|----------------------------------------|-----------------------------|
|                          | (1)          | (2)                                    | (3)                         |
| L.Energy returns         | -0.221***    | -0.225***                               | -0.260***                   |
| Δ Total COVID-19 cases   | -0.025***    | -0.027**                                | -0.023**                    |
| Δ Total COVID-19 deaths  | -0.014**     | -0.026***                               | -0.0478**                   |
| Δ New COVID-19 deaths    | -0.011***    | -0.029***                               | -0.013***                   |
| School closing           | 0.939        | 0.935                                  | 0.963                       |
| Workplace closing        | 0.048**      | 0.034*                                 | 0.068***                    |
| Cancelling of public events | -0.017***   | -0.019***                               | -0.017***                   |
| Closing of public transportation | -0.015*** | -0.016***                               | -0.013***                   |
| Public information campaigns | -0.058***  | -0.061***                               | -0.067***                   |
| Restrictions of internal movement | 0.018*** | 0.018***                                | 0.019***                    |
| International travel controls | 0.001      | 0.107                                  | 0.074                       |
| Brent crude oil prices   | -0.018***    | -0.019***                               | -0.016***                   |
| Δ Total COVID-19 cases   | 0.019***     | 0.033***                                | 0.081***                    |
| Δ Total COVID-19 deaths  | 0.012***     | 0.034**                                 | 0.038***                    |
| Δ New COVID-19 deaths    | 0.011***     | 0.034***                                | 0.041***                    |
| Market capitalization    | 0.012***     | 0.027**                                 | 0.019***                    |
| Market-to-book ratio     | 0.026        | 0.024                                  | 0.025                       |
| Daily dummies            | Yes          | Yes                                    | Yes                         |
| Country dummies          | Yes          | Yes                                    | Yes                         |
| Hansan test (P-value)    | 0.719        | 0.688                                  | 0.756                       |
| AR(1) (P-value)          | 0.000        | 0.000                                  | 0.000                       |
| AR(2) (P-value)          | 0.228        | 0.244                                  | 0.211                       |

This table shows the impact of COVID-19 and non-pharmaceutical interventions on the volatility of energy returns around the globe. Energy market returns and market-to-book ratio are modeled as endogenous variables. Standard errors are not displayed. *, ** and *** denote significance at 10%, 5% and 1% levels, respectively.

Table 9
The effect of COVID-19 and government non-pharmaceutical interventions on energy returns: Alternative measures of energy returns (robustness check 4).

|                          | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) |
|--------------------------|-----|-----|-----|-----|-----|-----|-----|-----|-----|------|
| L.Energy returns         | -0.178*** | -0.036*** | -0.089*** | -0.049*** | -0.043*** | -0.171*** | -0.039*** | -0.138*** | -0.048*** | -0.044*** |
| Δ Total COVID-19 cases   | -0.019*** | -0.033*** | -0.081*** | -0.054*** | -0.076*** | -0.062*** | -0.035*** | -0.121*** | -0.036*** | -0.036*** |
| Δ Total COVID-19 deaths  | 0.027    | 0.103   | 0.028   | 0.034  | 0.037  | 0.027  | 0.086  | 0.028  | 0.034  | 0.034  |
| School closing           | 0.017*** | 0.066*** | 0.102*** | 0.016*** | 0.022*** | 0.018*** | 0.023*** | 0.013*** | 0.028*** | 0.028*** |
| Workplace closing        | 0.032*** | 0.034*** | -0.038*** | -0.057*** | -0.035*** | -0.026*** | -0.038*** | -0.012*** | -0.035*** | -0.036*** |
| Cancelling of public events | -0.037*** | -0.278*** | -0.108*** | -0.054*** | -0.039*** | -0.094*** | -0.280*** | -0.045*** | -0.055*** | -0.065*** |
| Closing of public transportation | -0.011*** | -0.048*** | -0.016*** | -0.072*** | -0.057*** | -0.044*** | -0.018*** | -0.044*** | -0.018*** | -0.053*** |
| Public information campaigns | 0.014*** | 0.014*** | 0.015**  | 0.033**  | 0.016**  | 0.011**  | 0.056**  | 0.020**  | 0.027**  | 0.018**  |
| Restrictions of internal movement | 0.076     | 0.043   | 0.069   | 0.025  | 0.094  | 0.074  | 0.060  | 0.049  | 0.223  | 0.092  |
| International travel controls | 0.023*** | 0.027*** | 0.052*** | 0.058*** | 0.028*** | 0.023*** | 0.002*** | 0.047*** | 0.057*** | 0.028*** |
| Brent crude oil prices   | -0.012*** | -0.027*** | -0.019*** | -0.011*** | -0.018*** | -0.043*** | -0.028*** | -0.105*** | -0.027*** | -0.096*** |
| Market capitalization    | -0.016    | 0.045    | -0.014   | 0.085   | -0.099*** | -0.096   | 0.028   | -0.016   | 0.045   | -0.093*** |
| Market-to-book ratio     | Yes       | Yes       | Yes      | Yes    | Yes    | Yes    | Yes    | Yes    | Yes    | Yes    |
| Daily dummies            | Yes       | Yes       | Yes      | Yes    | Yes    | Yes    | Yes    | Yes    | Yes    | Yes    |
| Country dummies          | Yes       | Yes       | Yes      | Yes    | Yes    | Yes    | Yes    | Yes    | Yes    | Yes    |

This table shows the impact of COVID-19 and non-pharmaceutical interventions on the volatility of energy returns around the globe. Standard errors are not displayed. *, ** and *** denote significance at 10%, 5% and 1% levels, respectively.
Appendix A. Variable definitions and data sources

| Variable                                      | Definition                                                                 | Source                        |
|-----------------------------------------------|---------------------------------------------------------------------------|-------------------------------|
| **Dependent variables**                      |                                                                           |                               |
| Energy return                                 | The return of energy i on day t.                                           | Bloomberg                     |
| Energy return _t−1_                          | The return of energy i on day t−1.                                         | Bloomberg                     |
| **COVID-19:**                                |                                                                           |                               |
| ΔTotal COVID-19 cases                         | The daily growth in the total number of COVID-19 confirmed cases in country j at day t−1. | Johns Hopkins University (JHU) |
| ΔNew COVID-19 cases                           | The daily growth in the new number of COVID-19 confirmed cases in country j at day t−1. | Johns Hopkins University (JHU) |
| ΔTotal COVID-19 deaths                        | The daily growth in the total number of COVID-19 confirmed deaths in country j at day t−1. | Johns Hopkins University (JHU) |
| ΔNew COVID-19 deaths                          | The daily growth in the new number of COVID-19 confirmed deaths in country j at day t−1. | Johns Hopkins University (JHU) |
| **Non-pharmaceutical interventions:**         |                                                                           |                               |
| School closures                               | This variable is determined by recording closings of schools and universities. It is an indicator rated between 0–3, where 0 - no measures, 1- recommend closing or all schools open with alterations resulting in significant differences compared to non-Covid-19 operations, 2- require closing (only some levels or categories, e.g. just high school, or just public schools), and 3 - require closing all levels. | Johns Hopkins University (JHU) |
| Workplace closures                           | This variable is determined by recording closings of workplaces. It is an indicator rated between 0–3, where 0 - no measures, 1 - recommend closing (or recommend work from home), 2 - require closing (or work from home) for some sectors or categories of workers, and 3 - require closing (or work from home) for all-but-essential workplaces (e.g. grocery stores, doctors). | Johns Hopkins University (JHU) |
| Cancelling of public events                  | This variable is determined by recording cancelling public events. It is an indicator rated between 0–2, where 0 - no measures, 1 - recommend cancelling, and 2 - require cancelling. | Johns Hopkins University (JHU) |
| Closing down of public transport             | This variable is determined by recording closing of public transport. It is an indicator rated between 0–2, where 0 - no measures, 1 - recommend closing (or significantly reduce volume/route/means of transport available), and 2 - require closing (or prohibit most citizens from using it). | Johns Hopkins University (JHU) |
| Public information campaigns                 | This variable is determined by recording presence of public information campaigns. It is an indicator rated between 0–2, where 0 - no Covid-19 public information campaign, 1 - public officials urging caution about Covid-19, and 2- coordinated public information campaign (e.g. across traditional and social media) | Johns Hopkins University (JHU) |
| Restrictions on internal movement controls   | This variable is determined by recording restrictions on internal movement between cities/regions. It is an indicator rated between 0–2, where 0 - no restrictions, 1 - screening arrivals, 2 - quarantine arrivals from some or all regions, 3 - ban arrivals from some regions, and 4 - ban on all regions or total border closure. | Johns Hopkins University (JHU) |
| **Oil price:**                                |                                                                           |                               |
| Brent crude oil prices                        | The daily change in Brent crude oil price indicators on day t.              | Bloomberg                     |
| WTI crude oil prices                          | The daily change in WTI crude oil price indicators on day t.                | Bloomberg                     |
| **Control variables:**                        |                                                                           |                               |
| Market capitalization                         | The natural logarithm of daily market capitalization of firm j on day t.     | Bloomberg                     |
| Market-to-book ratio                          | The natural logarithm of daily market-to-book ratio of firm j on day t.      | Bloomberg                     |

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