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Examining the dynamic effect of COVID-19 pandemic on dwindling oil prices using structural vector autoregressive model

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**A B S T R A C T**

Emergence of COVID-19 pandemic in China hit oil prices most, traded at a negative for the first time ever in the international oil market. In this paper, we examine the dynamic effect on four major oil prices of COVID-19 with reference to China and Nigeria. We use daily frequency data, and employ structural vector autoregressive method for the analysis. We find that the impact of COVID-19 pandemic accounted for smallest shares of movement in Bonny and Daqing oil prices, only 14% in China’s Daqing and 17% in Nigeria’ Bonny, and the effect is even weaker on BRENT and WTI, 7% on each price as forecast error parameters indicate. This shows that the impact of infections of COVID-19 can short-lived and leave a minimal impact on economies, but the reaction of the market itself is subject matter. Thus, it is predicted that oil prices are likely to rise in future weeks as oil demand and major economies are expected to fully open and quickly recover. China may need to take advantage of the present low oil price to benefit its economy, while Nigeria may need to be careful in external borrowing binge embarked on to cushion the effect of oil price falls as it may debt-trap the economy.

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1. Introduction

The world economy was expectedly to improve in the first quarter of 2020, especially oil-dependent economies whose mainstay of their economies rely on crude oil for sustainability. However, coronavirus (COVID-19) cut the global economy plans beyond preparedness for the growth and development. The rapid and wide spread of pandemic infection of coronavirus outbreak, started in China in December 2019, led to economic lockdown and disrupted major economies across the globe. The adverse effect of coronavirus is severe on world economy, particularly on world oil market than the SARS outbreak, 2002/2003, and financial crisis, 2007/2008 or Middle East conflict — Gulf war, 1990 and shale revolution, 2011. The pandemic was initially appeared as biological weapon but it disruptive effect on oil sector threatened economic markets that raised a serious concern. The pandemic created oil glut as excess supply loomed and the demand declined as energy-use industries and energy retail sales suffered historic drops. China, where COVID-19 emerged, is a net importer of oil from Africa and Middle East and a major oil market determinant together with the US and India. The contractions in the oil market due to the pandemic infection of COVID-19 in both oil exporting and importing countries account for a drastic slip-down of oil prices in the fourth quarter of 2019 and second quarter of 2020.

Before the outbreak, the oil prices rebound that signaled a better economy for Organisation of petroleum Exporting Countries (OPEC). Specifically, the prices of Brent, West Texas Intermediate (WTI) and OPEC basket rose to $64.56, $53.79 and $62.94 per barrel, respectively, for the first time in the first quarter of 2019 and the face-off that broke between United States and Iran in January 2020 led to increase in the price of WTI above $70 per barrel. However, the COVID-19 outbreak pushed the price down in the international oil market, hard hit by the outbreak. The disease wrecked the world economy as a result of economic activities close-down across the globe. Specifically, between March and May 2020, the peak period of COVID-19 pandemic in affected countries, oil prices were not volatile as often known to be in the literature but highly precarious. The WTI is worst hit, it dropped to negative. Fall in oil prices is owed to the decline in oil demand of the largest oil net consumers: China, Japan and India, which reduced the rate of growth in crude demand in 2020 to 0.2 m b/d from 0.9 m b/d.

On the demand side, Europe, America and Asia are key player in the world oil market, and on the supply side, Middle East and Africa are key player, the two sides of which have cointegrating...
relationship with major world oil prices. The demand behavior for oil commodity could probably be significant in determining the market oil prices but the oil importing countries do not have pricing power as the market is semi-perfectly competitive because oil prices in the market are driven by OPEC and other international benchmark prices. The seven major oil prices in the market are Brent price, used to represent Europe, WTI price, represents the US, Dubai price, represents the Middle East, Bonny, represents Africa, Tapis and Minas, represents East Asia, and Daqing, represents China. The prices reflect the heavy dependence of the countries in the continents on the international crude oil market.

Oil price affects the growth and development of oil-dependent economies and economic activities of many industrialized countries world over. A body of studies in the literature looked at the impact of oil price on macroeconomic variables such as GDP, interest rate, inflation rate, stock prices and food prices, oil supply shock, oil demand shock, and oil inventory, among others (Refs [1–9]). Recently, Gob, Chen and Lin [10] argue that the impact of nonmarket factors, such as epidemic disease, prevalence conflict and war, are more important in determination of oil prices. They emphasize that such events are often significantly influence oil prices, area rarely explored.

Recently, the spread of COVID-19 pandemic pose a serious threat to world economic sectors, especially oil sector. Oil price dropped sharply resulting from the global COVI-19 pandemic, to which many economies struggled with severe lockdown measures. Brent crude oil prices slipped to $32.25 per barrel in March 2020, and fell as low as $18.11 per barrel in April, the same year. WTI that stood at an average of $31.72 per barrel in March slipped to $19.23 per barrel as at April. These prices were pushed down from an average of $64 per barrel in December 2019. However, two important issues still remain. First, the spillover effect of COVID-19 on oil prices may not be same and this will have different impacts on economies. Second, although major crude oil prices in the international oil market may be connected, however, the responses of these prices to the COVID-19 pandemic may differ which may differently measure how one economy suffers than the other during the period. It is therefore important to study the response of this commodity prices over COVID-19 period to predict the extent international oil market and oil economies are affected by the pandemic and how such response affect the oil market indicators — the demand and supply. More so, in the literature, oil price is considered to be highly volatile, the nature which has been argued to be determined by the market and policy shocks; and that, in the past, the negative shock has not slipped the price to lower than $20 per barrel (see Ref. [11]). However, the international oil price is currently below $15 per barrel which is due to COVID-19 outbreak that emerged in China, but it has been put forward that China has low pricing power in the international oil market [12]. Also, it is evident that oil prices are synchronous in the event of shocks and this is mostly hinged on “one great pool” hypothesis, is this also true for oil prices in the emergence of COVID-19 shock? To understand these issues, there is need to examine responsiveness of oil prices to COVID-19 pandemic using sound and transparent data. This, inter alia, will provide an opportunity to obtain realistic research result about the impact of COVID-19 event on oil price in domestic and international oil markets and will serve as a barometer for evaluating probable impact of such nonmarket factors on oil economy. The findings of this study can be generalized and will help the oil-dependence governments in their post-COVID full-fledged opening economic plans.

2. COVID-19 and oil price nexus

Oil-economies are those that are heavily depend on oil for growth and development. The said economies are not only the oil exporting countries whose huge annual revenue comes from oil supply but including also oil importing countries whose demand for oil for industrial consumption is high, such as US and China. Before the COVID-19 disease strike in the last month of 2019, crude oil imports by China has yearly been increasing. On demand side, for instance, trailing the US, China consumed 12.304 thousand of crude oil barrel daily in 2016 and the consumption rose to 12,840 and 13,525 of crude oil barrel daily in 2017 and 2018 respectively. In 2018, the world growth rate of oil consumption grew by an above average 1.4 million b/d or 1.5% with which China oil demand of 0.9 million barrel per day, accounted for 5.3% annual growth rate in the year, almost two-third of the global increase [13]. During the same period, the country’s oil consumption growth rate was greater than the Gross Domestic Product (GDP) growth rate. The high dependence of Chinese economy on imported crude oil makes the country the second largest consumer of oil after the U.S. (Chen, Zhu and Li [14]; Gong et al. [10]; Zeng and Li [15]).

Several factors, especially the growth and high level of development attained in China, contributed to China’s increase in crude oil imports in 2019, as likely the case in other high-income countries. A high refinery runs and expansion of the capacity of refineries and inventory stockpiling, particularly petrochemicals, and a decline in domestic oil production as well as increase in growth rate and infrastructure development are key drivers of the increase in energy consumption in China. years back (See EIA reports on China’s crude oil consumption for detail). However, during the spate period of the COVID-19 pandemic in the country, between January–February 2020, GDP was contracted by 6.8% as its main components were ruinously affected. For instance, final consumption expenditure was contracted sharply to 4.4%, gross capital formation dropped to −1.5%, domestic demand sharply declined by −5.8% and net exports contracted by 1%, as well as industrial production declined by 13.5% (OPEC [16]). The consequence of this resulted in economic trap and eroded oil demand growth in the country.

China’s daily oil consumption declined to 0.6 million barrel in the first quarter of 2020 from 0.9 million barrel in the last quarter of 2019, and the country’s GDP dropped by 6.8% in the first quarter of 2020 mainly due to the impact of the outbreak of COVID-19 pandemic (OPEC [16]). The index case of COVID-19 in China is cyclical between January and March and at its peak between April and May (Fig. 1), and out of the 34 affected areas in the country Hubei in Wuhan, Guangdong, Henan, Zhejiang, Hunan, Anhui, Jiangxi and Jiangsu are most affected. As at March 01, 2020, the total daily cumulative cases of the pandemic confirmed stood at 79, 968. With increased trend of the COVID-19 case in the country, with no vaccine yet discovered for the treatment, the Chinese government closed down its economy in relation to all sorts of domestic economic activities and international growth-led businesses as part of curtailment measures to the spread of the disease within and out of China. Though, the authority currently reopens the economy to ease economic hardship faced by the citizenry and counters the threat of economic security that the COVID-19 poses, this generally represents the current condition of the demand side of oil market.

On supply side, oil supply decrease by 0.01 mb/d m-o-m to average 100.12 mb/d in January 2020 which in strong hold associated with the fast spread of COVID-19 outside China. The pandemic is seen to have disrupted many local and foreign economic activities. In particular, oil production and distribution across the globe is most hit. As projected, the developing countries, even oil-rich countries are more devastated by COVID-19 disease owing to poor status of health infrastructure in many of these countries, which may make containment of the disease difficult (Ojerinde [17]).
The oil prices are volatile and comove over the period [Fig. 1]. As they typically react to market shocks, likewise they respond to COVID-19 shock. In particular, WTI dropped to a historic low in late April, to about $-37 negative per barrel from an average value of about $30 per barrel in March 2020, exacerbated by a decline in oil demand owing to COVID-19 effect. The prices soared in early May to about $30 per barrel in March 2020, exacerbated by a decline in oil production in Nigeria fell from an average 2.05 million barrel daily or 3.0% growth rate to an average 1.4 million barrel daily. This is associated with lockdown measures over coronavirus pandemic adding to attacks on oil installations in the Niger Delta by militants, who are agitating for better deals from the government (NNPC [20]) and with dragging state of the economy, measured at an average of −4.4% (Guardian Newspaper, 2020). In another report it was disclosed that the effect of COVID-19 on oil price plunge has resulted in fall of the country’s revenue from oil that dropped by 31.1%, and that the economy may recede again to recession [18]. This, will, the second time if the predictable event occur, as the country receded to recession as a result of oil price slump in 2016.

The first novel coronavirus case was confirmed in Nigeria on February 27, 2020, when an Italian business arrived Nigeria and was diagnosed of the disease in Lagos. After which it spreads fast across the states and most hit the border and business cities. As at May 21, 2020, Nigeria recorded a cumulative of 7016 COVID-19 cases with Lagos state recorded the highest clinically confirmed COVID-19 cases, 3093; follow by Kano, 875; Abuja, 446; Katsina, 303; and Borno, 235. The disease spreads through community transmission, thus, like other affected countries, Nigeria government embarks on precautionary measures to detect the disease early, trace the contacts, isolate and treat the confirmed affected patients. The authorities also enforced the use of face masks, social and physical distancing and strongly advices frequent hand washing and the use of hand sanitizers to reduce the spread of the disease in the country. Domestic and international economies activities were locked down which contribute more to the dragging of the economy, oil sector and its value supply chain in particular. New data and empirical research as in this case study will be of great help to inform the decision-makers on the degree to which COVID-19 has affected economies, the result of which could be helpful to make decision on economic sustainability in post disaster.

3. Empirical model, data and method

Empirical model adopted in this study is based on Diebold and Yilmaz [21] who developed time series approach, recently replicated by Zhang et al. [12], to investigate the dynamic relationship

![Figure 1](image-url)
among international crude oil prices. The methodology is based on a vector autoregressive (VAR) method. The VAR model first developed by Sims [22] and it has been widely used in literature, mostly applied to investigate relationship between macroeconomic variables. A VAR model is expressed as:
\[ y_t = \alpha + B_1 y_{t-1} + B_2 y_{t-2} + \cdots + B_n y_{t-n} + \varepsilon_t \]
1
and reduced form:
\[ y_t = \alpha + B(L)y_t + \varepsilon_t \]
2
where \( y_t \) is a vector of endogenous variables, \( \alpha \) is a vector of intercepts, \( B \)'s are matrices of coefficients and \( \varepsilon_t \) is a vector of disturbances with \( \varepsilon_t \) = 0. Since it assumed that the dynamics of each variable are affected by the lags of all variables then, \( L \) represents the lag operator. The main advantages of the VAR model are that: first, it allows all variables in the model to be endogenous; and second, it does restrict arrangement of endogenous variables to a particular form; third it is useful for forecasting. However, the limitation of the model is that each equation specified under the model has no economic interpretation. For instance, a simple two-variable VAR model with only one lag is associated with six coefficients, therefore, researchers find it difficult in explaining all the coefficients spontaneously. This causes a problem to our purpose of analyzing dynamic effect of COVID-19 on oil prices, as the effect of COVID-19 in a VAR model cannot specifically interpreted. The problem is solved by using an impulse response function (IRF) and forecasting error variance decomposition (FEVD) method. Although, IRF has been censured to have weak power to capture other shocks that are outside the model, and FEVD known to be sensitive to order of variables. However, these problems are solved with structural shocks introduced in VAR model, known in the literature as structural VAR (SVAR). The reduced form of SVAR is estimated to enable the independent variables to have individual effect on dependent variable. This development has enhanced the applicability of VAR method in most recent macroeconomics empirical literature (Liu, Meng and Wang [23]; Ali, Zaman and Islam, [24]; Shokr, Abdul Karim and Zaidi [25]; Yeh, Hu and Lin [26]; Li, Iscan and Xu [27]; Kozluk and Mehrotra [28]). Employing SVAR procedure, we examine the dynamic effect of COVID-19 on crude oil prices for China and Nigeria. The choice for China is that the country is heavily depend on international crude oil market, second world’s largest oil-importer which can represent demand side of the market, and among the largest economies in Asia (Zhang et al., 2019). Nigeria is net exporter of crude oil of OPEC, sixth world’s largest oil-expoter whose economy is also heavily depend on oil market, which can represent supply side of the market, and largest oil-economy in Africa (Adedeji et al. [29]). We used two international oil prices, West Texas Intermediate (WTI) and Brent (BRT), which are primary benchmarks in the world crude oil market and have been used widely in the existing literature, also include two local oil prices Bonny (BNY) and Daqing (DQG) prices for crude oil produced in Nigeria and China, respectively, both are reference prices for exports and imports. We employed a structural VAR model to examine the effect of COVID-19 (COV) on oil price variables, and specified reduced form of SVAR model for China derived from Equation (2), with structural form parameter matrix (B), as:
\[ A_0 y_t = \alpha + \beta(L)y_t + B\varepsilon_{cht} \]
3
where \( A_0 \) and \( B \) are matrices of the structural form of the VAR model. For Nigeria, the specification is written as:
\[ A_0 y_t = \alpha + \beta(L)y_t + B\varepsilon_{ngt} \]
4
Multiplying Equation (2) by \( A_0^{-1} \), we write the general structural representation as:
\[ y_t = A_0^{-1}\alpha + A_0^{-1}\beta(L)y_t + A_0^{-1}B\varepsilon_t \]
5
writing Equation (5) in reduced form, we have:
\[ y_t = k + \beta(L)y_t + \mu_t \]
6
where \( k = A_0^{-1}\alpha \) and \( \mu_t = A_0^{-1}B\varepsilon_t \). Following Amisano and Gianinni’s [30] AB-model, we combine restrictions for A and B, so that the model for innovations becomes \( A_{ht} = B_{ht} \). As \( A_{ht} \) indicates \( K \times K \) elements in matrix \( A \) and \( B_{ht} \) indicates \( K \times K \) elements in matrix \( B \), then altogether we have \( 2K^2 \) elements in the structural form matrices, and the maximum number of identifiable parameters in these matrices is \( K(K+1)/2 \), thus we need \( 2K^2 - K(K+1)/2 \) restrictions for exact identification of the full model.
In order to identify the structural shocks, we imposed a set of contemporaneous restrictions on the correlations in our structural VAR model in Equation (2) to reflect the operating procedures. We specified reduced form of SVAR model for China derived from Equation (2) as:
\[ A_0 y_t = \alpha + \beta(L)y_t + \varepsilon_{cht} \]
7
and for Nigeria, the specification is written as:
\[ A_0 y_t = \alpha + \beta(L)y_t + \varepsilon_{ngt} \]
8
The structure of the economy is explicitly represented in the matrix \( A_0 \). Each equation is assumed to represent a specific instantaneous economic relation represented by oil prices. The innovations \( \varepsilon_{cht} \) and \( \varepsilon_{ngt} \) represent the exogenous shocks, i.e. COVID-19 shock in China and in Nigeria respectively, which are assumed to have i.i.d.(\( N(0) \)). Since we assume \( \varepsilon_t \) are exogenous shocks, they are orthogonal to each other; i.e. the variance matrix \( N \) is a diagonal matrix. As discussed above, our structural models comprised 4 endogenous variables under the specification for China and Nigeria separately. This produces the reduced form of innovations of \( A \) and \( B \) matrices for China as:
\[
\begin{bmatrix}
1 & 0 & 0 & 0 \\
-1 & 0 & 0 & 0 \\
-2 & 0 & 0 & 0 \\
-3 & 0 & 0 & 0
\end{bmatrix}
\begin{bmatrix}
\mu^{cov} \\
\mu^{dagg} \\
\mu^{u\varepsilon} \\
\mu^{u\beta}
\end{bmatrix}
= 
\begin{bmatrix}
0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0
\end{bmatrix}
\begin{bmatrix}
\varepsilon_{cht} \\
\varepsilon_{t} \\
\varepsilon_{bny} \\
\varepsilon_{bret}
\end{bmatrix}
\]
9
\[
\begin{bmatrix}
1 & 0 & 0 & 0 \\
-1 & 0 & 0 & 0 \\
-2 & 0 & 0 & 0 \\
-3 & 0 & 0 & 0
\end{bmatrix}
\begin{bmatrix}
\mu^{cov} \\
\mu^{dagg} \\
\mu^{u\varepsilon} \\
\mu^{u\beta}
\end{bmatrix}
= 
\begin{bmatrix}
0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0
\end{bmatrix}
\begin{bmatrix}
\varepsilon_{cht} \\
\varepsilon_{t} \\
\varepsilon_{bny} \\
\varepsilon_{bret}
\end{bmatrix}
\]
10
The specified models, 9 and 10, are over-identified as the restrictions required for exact identification of the full model are 21 restrictions in the case of four endogenous variables for each country. However, we conducted a formal test for over-identification as shown in the model estimation below. In both cases of identification, COVID-19, shock, cov, is specified in the first row of Equations (9) and (10). Based on local and foreign reports on COVID-19 pandemic in relation to economies of affected countries,
developed and less-developed, the disease does not spread as a result of crude oil prices volatility, and that local and inter-border transmission of the disease is not due to demand and supply in the domestic and international crude oil market. The second, third and fourth rows are arbitrary equations for crude oil prices as both the domestic and foreign oil prices are allowed to respond contemporaneously to COVID-19 shock, hitting the economy. Zhang et al. [12] observed that WTI and Brent response quickly to any shock, which is consistent with our specification, however, as they show, the former may likely to have upward quick response while the later may likely to have downward quick response. But in this present case, we assume that both prices are synchronous. Daqing, domestic oil reference price in China, and Bonny light, domestic oil reference price in Nigeria, may also negatively respond to COVID-19 event, as the two countries are net importer and exporter of oil, respectively (OPEC [16]). This justified our assumption that the two foreign and domestic oil prices react negatively to outbreak of COVID-19, as the spate of the disease resulted to economic lockdown in affected countries and devastates the growth and development of economic activities, supply and demand crude oil in particular. Thus, there is no much different in the identification schemes in the response functions of the oil prices.

Daily frequency data were used for the analysis, spanned from March 20, 2020 to May 28, 2020. This is peak period of the COVID-19 pandemic in Nigeria and the end period at which China first recorded zero of new case and the period at which oil prices and oil demand fell simultaneously due to outbreak of the coronavirus, reversing the law of demand. At end of this period, the new cases recorded in Nigeria is constant with only single unit index different in many cases and also single index recorded in China. The daily COVID-19 data, measured as new clinically confirmed cases in last 24 h, are extracted from World Health Organization (WHO) situation report 61–133 series; WTI and Brent crude oil prices extracted from Energy Information Administration (EIA) and Bonny and Daqing domestic crude oil prices are obtained from Central Bank of Nigeria (CBN) and Oil price databases, respectively. The period of this study comprised a total of 73 observations. The choice of selecting the oil prices is that they provide better estimates and the four are commonly being used as reference or benchmarks in most domestic and foreign crude oil trade (Zhang et al. [12]). The WTI and Brent have been seen in literature to highly correlate with the other major oil prices in the international oil market and commonly used in oil-price related studies. Likewise Bonny spot price and Daqing are reference for oil exports and imports for Nigeria and China respectively. We replace the missed oil prices data with average of the preceding and succeeding days. The oil prices are in U.S. dollars per barrel. A single negative point of WTI is considered as an outlier, follow Ibrahim and Chancharoenchai [31], we replaced the point with an average point. All variables are expressed in natural logarithms.

The data are non-stationary at levels based on the augmented Dickey-Fuller and Phillips-Perron tests, but they all stationary when first-differenced indicating that the variables are cointegrated. In this case, the Ordinary Least Squares (OLS) method can deliver consistent estimates of the parameters. Thus, OLS is used to estimate the reduced form VAR models in examining the degree of relationship between the variables.

The VAR order of the models are determined from the results of misspecification tests and two lag lengths is found to be sufficient, suggested by Schwarz information criterion, to obtain a model fit, and stability test was conducted using Cholesky tests. The variables almost pass all the diagnostic tests but COVID-19 N and DOG models failed the normality test. Despite that all the variables are stationary at first differences, if the variables are cointegrated, the reduced form VAR models in first differences are misspecified. Checking eigenvalue and trace statistics for cointegration rank test, the coefficients are lower than the critical values at even 5%, indicating that there is no evidence of cointegration in the systems. Ramsey's RESET tests for Nigeria (25.034; p-value = 0.00) and China (20.749; p-value = 0.00) model stability do not indicate misspecification concern. Since the diagnostic tests do not suggest any serious modelling error, we estimate the Structural VAR models using maximum likelihood, the variance-covariance of the A and B matrices specified and the restrictions imposed in the models. The maximum was specified by numerical optimization method using scoring algorithm (see Table 1).

4. Results

Table 2 presents the structural parameter estimated for A and B matrices for the two economies. The likelihood ratio test for over-identification restrictions for the two economies cannot be rejected at better 5%. The χ²(1) test statistics for China and Nigeria are 3.535 and 0.472, respectively, with the corresponding p-values 0.060 and 0.492, respectively.

In Table 2, the estimated coefficients of the parameters that show contemporaneous impacts of COVID-19 on oil prices as it affected China’s and Nigeria’s economies may not be so interesting, but their signs worth discussion, and we present the negation of the A matrix to make the discussion easier. For China, the coefficient for COVID-19 is not consistent with our assumption as the near-term expected sign turned to be positive in Daqing oil price response function. This could probably be as a result of demand factors that positively influence the Daqing price fluctuation as well as oversupply in the oil international market resulting from economies lockdown effect. However, for Nigeria, Bonny light spot price also has the same sign, as evidenced considering parameters −β21 and −β21. This is possible as COVID-19 pandemic is an unprecedented event that directly affect macroeconomic variables that influence oil prices. Nonetheless, it appears that Nigeria Bonny light price is more hit from the ruinous effect of COVID-19 probably due to limited oil demand and falling consumption. In line with OPEC inter-month report [16] forecast, the oversupply of oil resulting from the global COVID-19 containment measures which caused severe fall in Nigeria Bonny light spot oil price, and this had considerable negative impact on the country’ growth. The impact of COVID-19 pandemic impaired Brent and WTI prices as the pandemic pushed down world economy causing the prices to sharply fall, and the latter is more hit as parameter −β21 indicates. This reflects the OPEC [16] claim that in April WTI was retracted, traded at a negative price for the first time ever, settling at minus $37.63 per barrel in the international oil market, when the sellers even heavily reduced their prices to find a market for their oils. This highlights how oil price can react to unprecedented events that restrict demand and economy. Interestingly, there is positive relationship among the oil prices, in long-term, WTI and Brent are likely to increase in response to China’s Daqing spike shock, as well as in Nigeria’s Bonny light spot prices as the parameters indicate.

In SVAR, instantaneous responses of variables are relatively less important and limited in statistical significance as important information are often derived from structural impulse response analysis. Thus, in Fig. 2, we display the impulse responses of China Daqing oil price to COVID-19, and the responses of WTI and BRT, international oil prices, within the estimated structural equations. Taking advantage of the better small sample properties of bootstrapping method, 95% percentile confidence intervals was constructed with 1000 replications for the impulse responses. We allow the responses up to 10 periods, month-on-month ahead. The unprecedented shock of COVID-19 in China has a statistically
Note. Jarque-Bera test for normality; LM is test for serial correlation. ADF and PP tests, include only constant, test for stationarity. P-values are in parentheses. * & ** signify 1% & 5% significance levels, respectively. The optimal lag order for the tests are suggested by Schwarz Information Criterion (SIC). CVD-19C = COVID-19 cases confirmed in China, and CVD-19 N – COVID-19 cases confirmed in Nigeria under the period of the study. WTI, BRT, DQG and BNY have been defined in the text.

Table 1
Summary and diagnostics statistics.

| Diagnostics   | WTI    | BRT    | DQG    | BNY    | CVD-19C | CVD-19 N |
|---------------|--------|--------|--------|--------|---------|----------|
| Mean          | 3.072  | 3.114  | 3.106  | 2.963  | 2.985   | 4.162    |
| Median        | 3.086  | 3.141  | 3.176  | 2.932  | 2.852   | 4.596    |
| Maximum       | 3.547  | 3.584  | 3.381  | 3.552  | 5.864   | 5.964    |
| Minimum       | 2.187  | 2.210  | 2.531  | 1.967  | 0.000   | 1.098    |
| Std. Dev.     | 0.309  | 0.284  | 0.218  | 0.394  | 1.522   | 1.426    |
| Skewness      | −0.506 | −0.350 | −0.962 | −0.245 | −0.189  | −0.545   |
| Kurtosis      | 2.823  | 3.038  | 3.007  | 2.222  | 1.831   | 1.995    |
| Jarque-Bera   | 3.081  | 1.513  | 10.789 | 2.462  | 4.399   | 6.418**  |
| Lag order     | 1      | 2      | 4      | 2      | 3       | 3        |
| LM            | 0.071  | (0.790)| 0.212  | (0.645)| 0.553   | (0.457)  |
| ADF – level   | −1.362 | −1.082 | −1.606 | −0.854 | −0.640  | −1.576   |
| PP – level    | −1.385 | −1.571 | −1.843 | −1.178 | −2.421  | −2.168   |
| ADF – Δ       | −8.751*| −12.120*| −3.661*| −10.954*| −13.569*| −10.079* |
| PP – Δ        | −8.751*| −12.243*| −9.848*| −10.842*| −19.330*| −17.069* |
| ** & ***      |       |       |       |       |         |          |

Table 2
Structural coefficients of A and B Matrices.

China

| China | B | A | LR |
|-------|---|---|----|
| 1     | 0 | 0 | 0  |
| 0.006 | 1 | 0 | 0  |
| 0.021 | 0.117 | 1 | 0  |
| 0.033*** | 0.455** | 0 | 1  |
| 0.752* | (0.065) | 0 | 0  |
| 0     | 0.065* | (0.006) | 0 | 0  |
| 0     | 0     | 0.107* | (0.009) | 0 |
| 0     | 0     | 0.114* | (0.010) | 0 |
| 1     | 0     | 0 | 0  |
| 0.065* | 1 | 0 | 0  |
| 0.009 | 0.640* | 1 | 0  |
| −0.010 | 0.453** | 0 | 1  |
| 0.674* | (0.057) | 0 | 0  |
| 0     | 0.125* | (0.011) | 0 | 0  |
| 0     | 0     | 0.827* | (0.007) | 0 |
| 0     | 0     | 0.109* | (0.009) | 0 |

Nigeria

| Nigeria | B | A | LR |
|---------|---|---|----|
| 1     | 0 | 0 | 0  |
| 0.065* | 1 | 0 | 0  |
| 0.009 | 0.640* | 1 | 0  |
| −0.010 | 0.453** | 0 | 1  |
| 0.674* | (0.057) | 0 | 0  |
| 0     | 0.125* | (0.011) | 0 | 0  |
| 0     | 0     | 0.827* | (0.007) | 0 |
| 0     | 0     | 0.109* | (0.009) | 0 |

Note. Parentheses contain the standard errors. P-values are in brackets. * & ** signify 1% & 5% significance levels, respectively.

significant impact on Daqing oil price as the price drastically fall. However, the fall in price does not benefit the economy as the restrictive measures implemented to stop the spread of COVID-19 in China disturbed economic activities on a larger scale which curtailed taking advantage of the cheap price of oil. The COVID-19 shock also slumps WTI and Brent prices resulted from global economic halt, the magnitude of the impact of COVID-19 pandemic shock appears to be severe on these two prices. Daqing appears to likely able to return to equilibrium shortly after the period forecasted. It is faster than WTI and Brent prices in returning to the stable point which may be obtained in the last period. The point estimates of the impulse response of WTI suggests that a one percent increase in the new COVID-19 case lowers WTI price by average 0.03%. The impact of COVID-19 in China may linger for about six months given that the country experienced peak infections that affected the country’s consumption and dragged the growth of the economy. The China data show that WTI and Brent may still remain below the benchmark of many oil-rich countries, whose budgets are planned on oil, a situation that may worsen the implementation of their budgets. The WTI’s and Brent’s values are forecast to remain under pressure if the oil glut is not absorbed in the market and if unsold cargoes still accumulate in the Atlantic. The WTI and Brent has different impact on Daqing. Daqing responds positively to WTI and negatively to Brent. This reflects the different in short-term effects of WTI and Brent oil shocks on China’s Daqing oil price. This could be related to the fact that, as China eased its lockdown in early May, it imports crude oil from oil-countries that pegged their international trading currency with the U.S than the North Sea. However, there is synchronous response between WTI and Brent oil prices as specified in the model for Nigeria.

For Nigeria, Fig. 3 shows that Bonny light price responds cyclically to the outbreak of COVID-19 pandemic in the country. Likewise, the Figure shows that WTI and BRT nearly have the same shape with the pandemic. The impact of COVID-19 appears to be severe in Nigeria as oil prices may not substantially increase in the long-term due to partial ease of lockdowns in many oil importing countries and increase in rate of new infections in the country in May. The point estimates of the impulse responses suggest that a one percent increase in new infection lowers Bonny price by average 0.01% in shorter day, and by only average 0.04% in longer day. However, the days ahead for Nigeria may be harder than...
envisaged if demand for Nigeria’s oil supplies remains low and oil prices do not increase more than the country’s budget benchmark. This forecast is equally applied to other developing oil economies whose revenues are mainly generated from oil exports. Fall in all oil prices below the budget benchmark in Nigeria in April and May due to the COVID-19 lockdown in the country and lockdowns imposed by other countries prompted the authority in the country to revise its budget and source for alternatives for financing the deficit. Bonny light price follows the same pattern with WTI and Brent but it adjusts quickly to Brent shock than WTI shock, but the Brent inter-month spread is forecast to slightly decline lower than WTI. By implication, in line with OPEC [16] forecast, COVID-19 may likely subdue economies of major oil exporting countries for a longer days, possibly to extend to third quarter of 2020. However, the impact can be mitigated with ease of global COVID-19 related measures and implementation of credible economic growth stimulus packages.

To further examine the impact of COVID-19 pandemic shock on oil prices, we perform forecast error variance decomposition. The contribution of one variable to the forecast error variance of another variable h-period-ahead is computed and we interpret the results as how much in percentage of the variation in one variable is explained by other influencing variables in the model. We only interested in structural forecast error variance of COVID-19 on selected oil prices and the contribution of each price relative to other prices. These are reported in Table 3. We consider 1–3 months forecast as short-run period and 5–10 months as long-run due to volatility nature of oil prices and quick transmissibility of COVID-19. In short-run, all oil price variables, WTI in particular, exhibit strongly endogeneity. The statistical significant of most of the estimates implying that the oil prices are influenced by the pandemic but the impact is negligible. In the 3-month horizon, the influence of this shock to the variability in the WTI is only 4.7% and slightly increased to 7.5%, in the 10-month. While Brent oil price is weakly endogenous, as the influence on the variable itself appears to be low even in the long-run, 10-month horizon. The response of Brent oil price to COVID-19 shock is also nearly negligible as only 7.1% (under China) and 14.3% (under Nigeria) variability in Brent can be explained by COVID-19 shock in the 10-month horizon, indicating that the influence of COVID-19 on Brent price is a trivial. These results suggest that, of the four types of oil prices, falling in the oil prices in the international oil market is little attributed to COVID-19 but the curbing measures globally implemented to stop the spread of the infections caused a grievous impact on the prices. Both WTI and Brent may likely have a strong endogenous influence on Bonny oil price than Daqing. This is consistent with two assertions that, first, the oil consumers more often have a weak negotiating power in the international oil market, and second, that the oil consumers’ organization does not exist, if it does, it is strong to influence oil price compare to oil suppliers under the aegis of Organization of Petroleum Exporting Countries (OPEC).

Turning to our main focus, interestingly, Table 3 suggests that COVID-19 pandemic is not a major retractile factor of variations in oil prices in any of the economies. The COVID-19 event accounted for smallest shares of movement in Bonny and Daqing oil prices, only 14% in China’s Daqing and 17% in Nigeria’ Bonny after 10 months, while a high variation of 64% and 41% can be explained by WTI shock in Daqing and Bonny, respectively. This shows that the impact of infections of COVID-19 can short-lived and leave a minimal impact on economies, but the reaction of market itself is...
Fig. 3. Responses of oil prices to COVID-19, Nigeria. The horizontal axis is the period, fixed at 10 months, and the vertical axis is the response of dependent variables to independent variables.

Table 3
Proportions of forecast error in oil prices over COVID-19.

| FH | China | Nigeria |
|----|-------|---------|
|    | COVID-19 | Daqing | WTI | Brent |
|    |    |    |    |    |    |    |    |    |
| Daqing |       |       |       |       |       |       |       |       |
| 1   | 0.005 | 0.994 | 0.000 | 0.000 | 0.159 | 0.840 | 0.000 | 0.000 |
| 3   | 0.163 | 0.602 | 0.233 | 0.001 | 0.084 | 0.605 | 0.303 | 0.007 |
| 5   | 0.186 | 0.351 | 0.459 | 0.002 | 0.111 | 0.562 | 0.379 | 0.006 |
| 8   | 0.160 | 0.242 | 0.594 | 0.002 | 0.145 | 0.435 | 0.414 | 0.004 |
| 10  | 0.140 | 0.216 | 0.639 | 0.003 | 0.173 | 0.412 | 0.408 | 0.004 |

| Bonny |       |       |       |       |       |       |       |
| WTI |       |       |       |       |       |       |       |
| 1   | 0.050 | 0.060 | 0.889 | 0.000 | 0.013 | 0.164 | 0.821 | 0.000 |
| 3   | 0.047 | 0.047 | 0.897 | 0.007 | 0.017 | 0.127 | 0.850 | 0.003 |
| 5   | 0.036 | 0.051 | 0.904 | 0.005 | 0.039 | 0.134 | 0.814 | 0.011 |
| 8   | 0.051 | 0.052 | 0.888 | 0.009 | 0.073 | 0.151 | 0.762 | 0.012 |
| 10  | 0.075 | 0.050 | 0.864 | 0.010 | 0.095 | 0.159 | 0.733 | 0.011 |

| Brent |       |       |       |       |       |       |       |
| WTI |       |       |       |       |       |       |       |
| 1   | 0.021 | 0.005 | 0.050 | 0.923 | 0.071 | 0.347 | 0.006 | 0.574 |
| 3   | 0.018 | 0.035 | 0.471 | 0.474 | 0.040 | 0.298 | 0.359 | 0.301 |
| 5   | 0.019 | 0.033 | 0.618 | 0.330 | 0.080 | 0.285 | 0.435 | 0.198 |
| 8   | 0.039 | 0.035 | 0.682 | 0.245 | 0.116 | 0.278 | 0.463 | 0.141 |
| 10  | 0.071 | 0.034 | 0.680 | 0.215 | 0.143 | 0.277 | 0.454 | 0.124 |

Note: DV – dependent variables. FH – Forecast horizon. Columns marked in bold indicate impulse response dynamic statistically significance at least at the 10%. 
subject matter. This result is consistent with the main finding of Gong et al. [10] that the impact effect of shocks on oil price most often disappear within short period as market recovers. The share impact of Brent oil price is significant for Nigeria but of minor importance for the two economies, as the shock will only explain average 0.3% and 0.4% variation in Daqing and Bonny respectively, after 10 months. Though the share varies little over time. These empirical results are similar with the empirical results of Chen et al. [14] for China’s inflation and oil price shock and Sharif et al. [32] for the US-COVID-19 infected cases and oil price volatility. Sharif et al.’s [32] study reveals that COVID-19 has implications on low oil price due to travel restrictions and low out output growth in China and European countries but this will shortly disappear as economies recovered. Also, Nguyen et al.’s study [33] reveals that prices of dependence commodities are likely to rise shortly after market crash, as the forces of supply and demand will influence the price to rise above the crashed price.

On world oil price models, we find significant impacts on WTI and Brent prices of the COVID-19 transmissibility shock for China and Nigeria. However, the infectious shock in Nigeria is high, probably being a net oil-exporter, compared to China, consistent with OPEC report [16] that the rate of new infections is presently high in that either oil. Similarly, Daqing shocks to WTI and Brent are minor as the influence power of the price is forecast to be weak. This reflects the low pricing power of China in the international oil market, supporting the argument that East Asia economies often pay a premium in the international crude oil market [12]. Thus, Chinese government may need to take advantage of the present low oil price to benefit its economy and, in post-COVID-19 period, it may need to change its leverage and respond properly to market conductive properties. Expectedly, the estimated pass-through is higher for Nigeria, being an oil-mono-economy, the point estimates average at 10% (WTI) and 14% (Brent) with effect after 8 months of the shock. Also, our results suggest that Bonny light price is relatively important and has a positive significant impact in the determination of both WTI and Brent prices. Bonny accounts for average determination of 16.4% and 34.7% in WTI and Brent, respectively, in the short-run and with no significant difference 10 months thereafter. Both prices are forecast to rise sharply in future weeks from the lows of April as oil demand and more economies are expected to fully open and quickly recover. Little wonder OPEC and non-OPEC members (OPEC+) compel Nigeria, among other oil-export leading members, to comply with crude oil production quota to help shore up global crude oil prices. Intuitively, oil prices may soar sooner than expected and benefit oil-economies. Precautionarily, Nigeria should be careful in external borrowing binge recently embarked on to cushion the effect of oil price falls and the scourge caused by COVID-19. This, in our own observation, will increase inflation and steep depreciation of Naira, increase uncertainties in the short-term and in the long-term debt-trap the economy, consequence of which will jeopardize economic recovery plans of post COVID-19.

5. Discussion

In general, the findings of our study provides some important information on the impact of non-market shocks on oil prices fluctuations, focuses COVID-19 in this case. Specifically, the study stands that both supplier and consumer of oil may not benefitted in the event of non-market shocks. This is contrary to the existing debate that either oil supplier or consumer benefitted from market supply or demand shock, respectively. For instance, our study of daily frequency data of the dynamic impact of COVID-19 on dwindling of oil prices found that COVID-19 outbreak influenced China’s Daqing oil price to be positive. This conform to the oil market theory which states that oil demand factors have a positive impact on oil price fluctuation and that the supply factors have a negative impact on oil price fluctuation. By implication, Nigerian economy may likely recedes into recession in the last quarter of the year as the economy is heavily relied on oil revenue and oil prices may not substantially increase in the long-term due to COVID-19 scourge that poses threats to its major oil importing countries, including China. The days ahead for Nigeria may be harder than envisaged if oil demand remains low and oil prices do not increase more than the country's budget benchmark. This forecast is equally applied to other developing oil economies whose revenues are mainly generated from oil exports.

On one hand, the study reveals important characteristics of China’s Daqing oil price in the event of non-market shocks. First, the COVID-19 event only accounted for a small share of movement in China’s Daqing oil prices, only about 14% (Table 3). This may related to the fact that, with the increase of lag periods, the impact strength of COVID-19 shock gradually weakens, as such, the effect may be short-lived. It reflects in an obvious short-term effect. On the other hand, it can be deduced from our forecast results that despite the low international oil prices, accounted on oil supply surplus in the spot market resulting from outbreak of COVID-19 pandemic, in absolute term may find that COVID-19 from cheap prices. This is based on the fact that not only the country experienced peak infections that affect the country’s oil demand, but the epidemic led to the lockdown in the country and also drags the growth of the economy through the first and second quarter of 2020. This highlights how oil price can react to unprecedented events that restrict demand and economy.

The dynamic effect on four oil prices considered in this study is further scrutinized in Figs. 2 and 3 under impulse response. There are differences in the response strengths of oil prices to COVID-19 shock in relation to the response directions and tendencies of these prices. For instance, China’s Daqing appears to likely able to return to equilibrium shortly after the period forecasted, faster than WTI and Brent prices in returning to the stable point. Whereas Nigeria’s Bonny responds cyclically to the outbreak of COVID-19 pandemic up to second quarter of 2020 and exhibits persistence trend after the period. These results are not surprising because the individual oil price response reflects the different in shock absorptive capacity of the respective economies and the different in the roles they play in the international oil market.

6. Conclusion

In this paper, we examine the dynamic effect of COVID-19 pandemic on dwindling oil prices using structural vector autoregressive model with contemporaneous restrictions for two oil-economies. Taking demand and supply side of the oil market into consideration, data on COVID-19 daily transmissibility shock for China, second world’s largest oil-importer − represents demand side, and Nigeria, sixth world’s largest oil-exporter − represents supply side of the market and four major oil prices: WTI, Brent, Daqing; and Bonny light, were collected for the analysis. In the SVAR framework, the estimated parameters are statistically significant showing the contemporaneous impacts of COVID-19 on oil prices as it affected China’s and Nigeria’s economies but their signs are not consistent with our a prior assumption. This is not impossible as COVID-19 pandemic is an unprecedented event that directly affect macroeconomic variables that influence oil prices. However, in absolute term, we find that COVID-19 pandemic impaired Brent and WTI prices as the pandemic pushed down world economy which caused the prices to sharply fall. The WTI is more hit, traded at a negative price for the first time ever in the international oil market.
With the adopted identification scheme we are able to identify reasonable responses of oil prices to COVID-19 shock, and allowed impulse month-on-month responses of oil prices up to 10 periods ahead. For China, COVID-19 shock has a statistically significant impact on Daqing oil price as the price drastically fall. However, the fall in the price does not benefit the economy as the disease restrictive measures implemented in China disturbed the economy on a larger scale which curtailed taking advantage of the cheap price of oil. For Nigeria, the impact of COVID-19 appears to be severe as Bonny is tangled by the COVID-19 impact. Both the Bonny (local) and WTI and Brent (foreign) prices may not substantially increase in the long-term. Thus, the country may face an economic hard time than envisaged if demand for oil remains low and oil prices do not increase than the country’s budget benchmark. In addition, based on our forecast variance decomposition result, the COVID-19 event accounted for smallest shares of movement in Bonny and Daqing oil prices, while high variations in both prices can be explained by WTI shock. 

Conclusively, a major event like this should periodically be considered when formulating economic plans for economy to adapt to a change when abnormal changes occur and which could opening up other ways that would enable inclusive and economic sustainability. In this case, Chinese government may need to take advantage of the present low oil price to benefit its economy and, in post COVID-19 period, it may need to change its leverage and respond properly to market conductive properties. Meanwhile, Nigeria should be careful in external borrowing binge recently embarked on as this will increase inflation and steep depreciation of Naira, increase uncertainties in the short-term and in the long-term debt-trap the economy, consequence of which will jeopardize economic recovery plans of post COVID-19. An important implication is that the impact of infections of COVID-19 can short-lived and leave a minimal impact on economies, but the reaction of market itself is subject matter.

Credit author statement

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Declaration of competing interest

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

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