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Modelling economic policy issues

## Oil price shocks and inflation rate persistence: A Fractional Cointegration VAR approach



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### ABSTRACT

This study investigates the effect of oil price shocks on the inflation persistence of the top ten (10) oil-exporting and oil-importing countries. The study employs the recently developed fractional cointegration vector autoregressive (FCVAR) approach. It accounts for the role of monetary policy framework and exchange rate regime. It also tests and accounts for oil price asymmetry. The results show that inflation rate persistence of oil-exporting and oil-importing countries does not increase due to oil price shocks suggesting that the monetary policy of these countries accommodates oil price shocks, and may not necessarily be changed due to oil price shocks. This holds for countries operating floating regimes and inflation targeting, and those operating pegged regimes and non-inflation targeting monetary policy framework. The monetary policy of oil-importing countries appears to accommodate oil price shocks. As failure to account for oil price asymmetry tends to exaggerate inflation persistence for both oil-exporting and oil-importing countries, the conclusions do not change markedly. This result is consistent after accounting for oil price asymmetry, under positive and negative oil price shocks.

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## 1. Introduction

Maintenance of a stable inflation rate is arguably the primal macroeconomic objective of every central banker, and a task that requires a proper understanding of inflation rate dynamics such as inflation rate persistence (see Tule et al., 2019). A proper understanding of the dynamics of inflation rate persistence helps central bankers in making appropriate monetary policy decisions (Amano, 2007; Coenen, 2007; Tetlow, 2019). Inflation persistence is the time it takes for shocks to inflation rate to die out (Sbordone, 2007). According to Bilici and Çekin (2020), it can also be defined as the speed with which inflation returns to its equilibrium level (long-term mean) after a shock. The effectiveness of monetary policy strategy is defined by its ability to achieve low inflation rate persistence, as this indicates that shocks to inflation rate are eliminated within a short period (Meller and Nautz, 2012; Gerlach and Tillmann, 2012; Bratsiotis et al., 2015). Sbordone

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(2007) further explained that the implementation of a stabilisation policy with a wrong inflation persistence estimate can be costly, particularly, when the policymaker is minimising a welfare-based loss function.

Oil price shock is one of the prominent external shocks that influence countries' inflation rates (see Alvarez et al., 2011; Misati et al., 2013; Valcarcel and Wohar, 2013; Salisu et al., 2017; Sek, 2017; Lacheheb and Sirag, 2019; Nusair, 2019; Raheem et al., 2020). The potential effect of oil price shocks on countries' inflation rates indicates that inflation rate persistence of countries may be affected by oil price shocks. This position is further justified by Misati et al. (2013) which found that the effect of oil prices on inflation is more persistent than the effect of food prices. As lower inflation rate persistence corresponds to the efficiency of monetary policy (Meller and Nautz, 2012; Gerlach and Tillmann, 2012; Bratsiotis et al., 2015), an increase in inflation rate persistence of a country, as a result of oil price shock, would imply weakness in the effectiveness of the monetary policy of such country, and call for a monetary policy review in the face of oil price shock. On the other hand, a reduction or no change in inflation rate persistence as a result of oil price shock would mean that the current monetary policy is responsive to oil price shock, and no monetary policy review is required in the face of oil price shock.

The main objective of this study is to investigate the effect of oil price shocks on inflation rate persistence, particularly focusing on top net exporters and importers of oil, which are highly prone to oil price shocks (Salisu et al., 2017; Raheem et al., 2020). This study is important, particularly for monetary authorities, in determining whether or not to review monetary policies in the face of oil price shocks. Respected monetary economist, Ben S. Bernanke, has called for caution in the review of monetary policy in the face of oil price shocks (see Bernanke et al., 1997). He argued that the economy may suffer from the effect of monetary policy if monetary policy changes were initiated against a transient oil price shock. This position has been confirmed by recent studies including Kormilitsina (2011) and Olubusoye et al. (2015). Specifically, Kormilitsina (2011) found that monetary policy amplified the negative effect of the oil price shock on the US economy, while Olubusoye et al. (2015) found that the adverse changes in the interest rate and exchange rate in Nigeria was due to change in monetary policy and not oil price shock. Thus, this study analyses the effect of oil price shocks on inflation persistence, to minimise the economic cost of initiating monetary policy actions when oil price shocks do not increase inflation rate persistence.

Methodologically, inflation persistence has been examined using a univariate modelling framework, such as the autoregressive, fractional integration and time-varying parameter approaches (see Pivetta and Reis, 2007; Noriega and Ramos-Francia, 2009; Gaglianone et al., 2018; Granville and Zeng, 2019; Bilici and Çekin, 2020) or a multivariate modelling framework, such as Johansen cointegration or fractional cointegration (see Mahdavi and Zhou, 1997; Niemann et al., 2013; Civelli and Zaniboni, 2014; Lucey et al., 2017; Aye et al., 2017; Yaya et al., 2019; Geronikolaou et al., 2020). While univariate models consider the idiosyncrasies of inflation rate, via its autoregressive coefficients, as being the sole determinant of inflation rate persistence; the roles of other factors are considered by multivariate models.

As appropriate, this study employs a multivariate modelling framework in analysing the effect of oil price shocks on inflation persistence. Specifically, it relies on the fractional cointegration VAR (FCVAR) approach introduced by Johansen (2008) and further expanded by Johansen and Nielsen (2010, 2012), as against the conventional cointegration VAR (CVAR) alternative by Johansen (1996). As both CVAR and FCVAR analyse the long-run relationship between or among variables, CVAR assumes only two fixed cases of long-run relationship (absence - short memory or presence - permanent memory); as indicated by zero and first orders of integration,  $I(0)$  or  $I(1)$ , respectively). Whereas, FCVAR can assume varying orders of integration,  $I(d)$ , where  $d$  indicates any real-value order of integration, which allows for long memory transitory persistence ( $0 < d < 1$ ) (see Gil-Alana et al., 2017; Gil-Alana and Carcel, 2018; Granville and Zeng, 2019).

The choice of FCVAR over the cointegration VAR (CVAR) alternative is motivated by two main reasons. First, several studies have found inflation rate to be fractionally integrated (see for example Granville and Zeng, 2019; Tule et al., 2019; Bilici and Çekin, 2020), while Gil-Alana and Gupta (2014) revealed that oil price is also fractionally integrated. This suggests that FCVAR would be a better approach in analysing the long-run relationship between oil price and inflation rate as involved in the analysis of oil price shock inflation rate persistence modelling. Second, studies have shown that the effect of oil price shocks on inflation rate has reduced in recent years (see Valcarcel and Wohar, 2013; Choi et al., 2018; Lahiani, 2018; Chen et al., 2020). FCVAR is, thus, appropriate, as oil price shock may be expected to only have a marginal effect on inflation persistence of countries. CVAR model relies on the assumption of large change in inflation persistence, which may result in wrong conclusion (see Tule et al., 2019).

This study contributes to the empirical literature on the analysis of the degree and the determinants of inflation persistence in three distinct ways. First, it examines the effect of an external factor (oil price) on inflation persistence using fractional cointegration VAR. The earlier attempt to apply FCVAR approach to inflation persistence analysis was made by Tule et al. (2019). However, the study only examines the fractional cointegration among components of inflation (food, energy, and core inflation), which are all domestic factors. Other studies on inflation persistence and domestic factors include Noriega and Ramos-Francia (2009) and Gaglianone et al. (2018). To the best of our knowledge, this study will be the first to account for the relationship between an external factor (oil price) and inflation persistence. This innovation was motivated by the need for monetary authorities to properly understand the nature of external shocks, in determining whether monetary policy intervention is required or not, in the face of oil price shocks (see Bernanke et al., 1997).

Second, this study accounts for the role of country-specific monetary policy frameworks and exchange rate regimes in modelling the effect of oil price shock on inflation persistence of the selected countries. The effect of monetary policy framework on inflation persistence has earlier been explained by Gerlach and Tillmann (2012). The study revealed that

inflation targeting reduces inflation persistence. In like manner, the effect of exchange rate regime has been explained by [Wu and Wu \(2018\)](#), which found existence of higher inflation persistence under floating rates than under pegged rates. This study will contribute uniquely to the literature by accounting for the role of the two macroeconomic policies. This is considered important as recent studies have established the link between monetary policy framework (such as inflation targeting) and oil price shocks (see [López-Villavicencio and Pourroy, 2019](#)). Thus, this study will provide new evidence on the effect of oil price shock on inflation rate persistence under different monetary policy and exchange rate regimes.

Third, we investigate the existence and the role of oil price asymmetry in the oil price–inflation persistence relationship. Evidence from the recent studies revealed that inflation rate responds asymmetrically to changes in international commodity prices; indicating that the effects of positive and negative oil price shocks on inflation rate are different (see [Salisu et al., 2017](#); [López-Villavicencio and Pourroy, 2019](#); [Nusair, 2019](#); [Akinsola and Odhiambo, 2020](#); [Raheem et al., 2020](#)). Empirically, many studies have shown

that failure to account for asymmetry, when it exists and is significant, could lead to wrong conclusions (see for example [Akdoğan, 2020](#); [Salisu et al., 2017, 2019](#)). Thus, testing for asymmetry in oil price–inflation persistence, and accounting for same when it is significant, is expected to generate better empirical results. Asymmetry in the effect of oil price shocks on inflation persistence may imply that monetary authority would need to respond differently to positive and negative oil price shocks.

Following this introductory section, the remaining parts of the paper are organised as follows: Section 2 deals with literature review; some stylised facts and preliminary analyses are presented in Section 3; while Section 4 analyses the methodological framework for the study. Results and discussions are presented in Section 5, while Section 6 concludes the paper.

## 2. Literature review

Proper understanding of the nature and dynamics of a country's inflation persistence is important for its apex monetary authority; particularly, as it aids the central bankers in making effective monetary policy decisions towards maintaining price level and economic stability ([Bernanke et al., 1997](#)). According to [Sbordone \(2007\)](#), inflation persistence is the time it takes for shocks to inflation rate to die out. It can also be defined as the speed with which inflation returns to its equilibrium level after a shock ([Bilici and Çekin, 2020](#)). Many studies have examined the dynamics of inflation persistence in some countries and regions. Some of these studies believe that the dynamics of inflation persistence is determined by the dynamics of inflation rate in the economy. These studies employ univariate autoregressive modelling technique, such as stationarity test, fractional integration, fractional unit root or time-varying parameter (TVP) estimation approach (see for example; ([Antonakakis et al., 2016](#); [Bilici and Çekin, 2020](#); [Granville and Zeng, 2019](#); [Bratsiotis et al., 2015](#); [Darvas and Varga, 2014](#); [Gerlach and Tillmann, 2012](#); [Zhang, 2011](#)); among others). Other studies assume that inflation persistence could be influenced by structural economic factors, such as progressive taxation, human capital, and monetary policy framework — particularly, inflation targeting or exchange rate regime (see, for example [Geronikolaou et al., 2020](#); [Wu and Wu, 2018](#); [Canarella and Miller, 2016](#)).

There are fairly consistent results amongst studies considering idiosyncrasies of inflation rate of a country as the main determinant of inflation persistence. For example, [Granville and Zeng \(2019\)](#) examined the nature and dynamics of inflation persistence in the United States of America (USA). The study found that changes in inflation persistence were highly influenced by the expectations formed by memories of previous inflation. Using Turkey as a case study, [Bilici and Çekin \(2020\)](#) employed a TVP-estimation approach and revealed that inflation persistence continued to increase and remained unstable during periods of high inflation. Also, [Antonakakis et al. \(2016\)](#) utilised online and official price indexes for inflation persistence in selected countries (Argentina, Brazil, China, Japan, Germany, South Africa, the UK, and the US). Their study established that the degree of inflation persistence from the estimated long-memory parameter was relatively small when considering online price indexes as a measure of inflation. This implies that the efficiency of the monetary policies in the management of price stability was underestimated by official price indexes. [Bratsiotis et al. \(2015\)](#) examined the important role of inflation target in persistence of inflation using seven countries. Their finding showed that inflation persistence declined with inflation targets. Similarly, [Gerlach and Tillmann \(2012\)](#) analysed inflation persistence of Asia-Pacific countries, before and after the introduction of inflation targeting policy. They found that the speed at which persistence fell varied across countries, and that persistence tended to decline following the adoption of inflation targeting.

Some studies have considered structural factors as additional determinants of inflation persistence. Virtually all these studies focused on internal factors. These studies include [Geronikolaou et al. \(2020\)](#); [Wu and Wu \(2018\)](#); [Canarella and Miller \(2016\)](#) among others. In the study of 28 OECD countries, [Geronikolaou et al. \(2020\)](#) examined the impact of progressive taxation and human capital on inflation persistence. Their findings revealed that inflation persistence increased when there was an increase in progressive taxation. The distribution of human capital across sectors hindered labour mobility, as well as amplified inflation persistence. Similarly, [Wu and Wu \(2018\)](#) investigated the role of flexible exchange rate regime on inflation persistence using 23 industrial countries. There was ambiguity in the effect of exchange rate regime on relative inflation persistence; however, there was a strong indication of high inflation persistence under floating rates compared to pegged rates.

In the same vein, [Canarella and Miller \(2016\)](#) analysed the relationship between inflation targeting and inflation persistence of selected advanced (Canada, Sweden, and the United Kingdom), and newly industrialised and emerging

market (Chile, Israel, and Mexico) economies that adopted inflation targeting (IT) prior to the year 2000. They found overall mixed results that varied according to countries' level of development. Specifically, inflationary processes in the three advanced economies were fractionally integrated, stationary, mean-reverting, and share common inflation persistence. Whereas inflationary processes in the three emerging market economies were fractionally integrated, mean-reverting, non-stationary.

Our study falls within the class of studies that consider structural factors as additional determinants of inflation persistence. However, it focuses on an external factor, oil price, as against the domestic factors considered by the previous studies. It also focuses on oil-exporting and oil-importing countries, whose inflation persistence has not been investigated, particularly, with recognition of their economic structural peculiarity as oil-dependent countries. This innovation was motivated by the established empirical relationship between oil price and inflation rate of many countries (Ozdemir et al., 2013; Valcarcel and Wohar, 2013; Sek, 2017; Salisu et al., 2017; Choi et al., 2018; Nusair, 2019; Lacheheb and Sirag, 2019; Raheem et al., 2020). This study also tests and accounts for oil price asymmetry in modelling the effect of oil price shocks on inflation rate persistence. The significance of oil price asymmetry may be suspected, as related studies revealed the existence of the asymmetric effect of oil price shocks on inflation rate of oil-importing and oil-exporting countries (see Salisu et al., 2017; Nusair, 2019; Raheem et al., 2020).

The results of the effect of oil price shocks on inflation rate of oil-importing and oil-exporting countries have been mixed. For top oil-importing countries such as China and USA, there is evidence that the contagion effect of oil price shock on inflation rate has reduced (see Valcarcel and Wohar, 2013; Lahiani, 2018; Chen et al., 2020), suggesting that oil price shocks may not cause significant increase in inflation persistence of oil-importing countries. On the other hand, the study by Salisu et al. (2017) finds mixed short-run and similar long-run relationships between oil price and inflation rate for oil-importing and oil-exporting countries. This suggests that the empirical result for the effect of oil price shock on inflation rate persistence of oil-importing and oil-exporting countries may either be similar or vary.

Furthermore, virtually all the studies on oil price–inflation rate nexus examined cointegration between oil price and inflation rate on the assumption that the order of integration is integer-valued, using various cointegrated VAR (CVAR) approaches. Meanwhile, several studies have found inflation rate to be fractionally integrated, and the study by Gil-Alana and Gupta (2014) revealed that oil price is also fractionally integrated. This suggests that oil price and inflation rate can be fractionally cointegrated. Thus, the current study identifies the fractional integration properties of these two variables and employs fractional cointegrated VAR (FCVAR) approach. This makes the determination of the degree of fractional cointegration before and after accounting for oil price, and by implication, the assessment of the effect oil price shock on inflation persistence, possible. This innovation is novel, and may only be related to the work by Kruse and Wegener (2020) that examined the effect of relevant macro-financial variables on real oil price persistence.

### 3. Stylised facts and preliminary analysis

In this study, we explore data for Brent oil price and inflation rate of top ten (10) oil-exporting and oil-importing countries, over the period between January 2000 and December 2019. The period covered generates 240 observations and includes the periods of high and low inflation rates in the selected countries. It, however, excludes the period of the recent COVID-19 pandemic, to avoid its possible distortionary effect. The selected countries were identified based on the recent ranking of oil-exporting and oil-importing countries; with respect to the value of oil exports and imports in US\$.<sup>1</sup> As there are top oil exporters that also feature among the top importers, such as the United States and United Kingdom, our samples are better categorised as net exporters and net importers of oil using Enerdata (2019) Trade Balance statistics.<sup>2</sup>

The top 10 oil-exporting countries are: Saudi Arabia, Russia, Iraq, Canada, United Arab Emirates (UAE), Kuwait, Nigeria, Norway, Libya and Brazil,<sup>3</sup> while the top oil-importing countries are: China, the United States, India, Japan, South Korea, Netherlands, Germany, Spain, Italy and the United Kingdom. These countries employ varying monetary policy frameworks and exchange rate regimes. According to the International Monetary Fund (IMF), the *de facto* exchange rate regimes operated by countries can be classified into four; hard pegs (currency board and no separate legal tender), soft pegs (conventional peg, peg with horizontal band, stabilised arrangement, crawling peg and crawl-like arrangement), floating regimes (floating and free floating) and residual (other managed arrangement) (see AREAER, 2018). For ease of analysis, these categories are grouped into two; fixed/pegged arrangement and floating arrangement, since other groups aside floating are controlled. Similarly, while the IMF identified four categories of monetary policy frameworks; exchange rate anchor, monetary aggregate target, inflation target and others; we grouped these into inflation targeting and non-inflation targeting policy. Asides the ease of analysis, our groupings allow us to verify the established relationship between inflation targeting, floating & pegged exchange rate regime and inflation persistence.

To account for countries' monetary policy and exchange rate policy frameworks, this study relies on Mundel–Fleming open economy macroeconomic model (see Ramirez (2001, 2004) and Akdogan (2019)). Under the global reality of

<sup>1</sup> For the ranking oil exporting countries (see <http://www.worldstopexports.com/worlds-top-oil-exports-country/>), and for the ranking of oil importing countries (see <http://www.worldstopexports.com/crude-oil-imports-by-country/>).

<sup>2</sup> See <https://yearbook.enerdata.net/crude-oil/crude-oil-balance-trade-data.html>.

<sup>3</sup> Kazakhstan and Angola which are in the 8th and 9th position respectively were excluded due to non-availability of inflation rate data. This paved the way for Libya and Brazil, which are in the 11th and 12th position respectively, on the ranking.

**Table 1**

List of Top 10 Oil-exporting and Oil-importing countries.

Source: Compiled by the authors.

Oil-exporting countries	Oil-importing countries
Brazil <sup>a**</sup>	China <sup>b*</sup>
Canada <sup>a***</sup>	Germany <sup>a***</sup>
Iraq <sup>b*</sup>	India <sup>a**</sup>
Kuwait <sup>b*</sup>	Italy <sup>a**</sup>
Libya <sup>a**</sup>	Japan <sup>a***</sup>
Nigeria <sup>a**</sup>	Netherlands <sup>a***</sup>
Norway <sup>a***</sup>	South Korea <sup>a***</sup>
Russia <sup>a**</sup>	Spain <sup>a***</sup>
Saudi Arabia <sup>b*</sup>	United Kingdom <sup>a***</sup>
United Arab Emirates <sup>b*</sup>	United States <sup>a***</sup>

Note: Superscript “a” denotes inflation targeting countries, while “b” indicates non-inflation targeting countries. Also, superscript “\*\*\*” is for countries operating floating exchange rate regime, while “\*\*” is for countries operating pegged regime.

free capital mobility, this model indicates that a country operating floating exchange rate regime will have monetary independence, and could use interest rate as a policy tool to influence money supply and inflation in the economy. Whereas, countries operating fixed exchange rate regime will control money supply and inflation by buying and selling foreign currencies. Thus, in modelling inflation persistence of countries operating floating exchange rate regime, fractional cointegration was examined among inflation rate, interest rate and exchange rate, while same was examined among inflation rate, external reserves and exchange rate of countries operating fixed exchange rate regime. Data on inflation rate, foreign reserves for relevant countries, and nominal effective exchange rate were obtained from International Financial Statistics (IFS), while the data for Brent crude oil price and interest rate for relevant countries were obtained from US Energy Information Administration (US EIA).

**Table 1** presents the list of top ten (10) oil-exporting and oil-importing countries considered in this study. As evident, both oil-exporting and oil-importing countries consist of countries operating inflation targeting and non-inflation targeting regime, as well as floating and pegged exchange rate regime. It can, however, be observed that all exchange rate floating countries operate inflation targeting monetary policy framework, while countries operating pegged exchange rate operate non-inflation targeting monetary policy framework. There are four (4) oil-exporting countries operating floating exchange rate regime and inflation targeting (IT & FR). These are: Brazil, Canada, Norway, and Russia. Other six (6) oil-exporting countries: Saudi Arabia, Iraq, Kuwait, Nigeria, Libya, and UAE, operate pegged exchange rate regime and non-inflation targeting (NIT & PR). As regards the oil-importing countries, only China operates pegged exchange rate regime and non-inflation targeting monetary policy framework, while the other nine (9) countries operate floating exchange rate regime and inflation targeting.

The trends in oil price and inflation rate for oil-exporting and oil-importing countries are presented in **Figs. 1** and **2**. Observing the scale of inflation rates in **Figs. 1** and **2**, it is evident that inflation rates of oil-importing countries are lower and less volatile compared to that of the oil-exporting countries, which appear higher and more volatile. This was further corroborated by the descriptive statistics for the specified groups presented in **Table 2**, where the average inflation rate for oil-exporting countries is 4.94 percent with 5.27 standard deviation, compared to the average inflation rate for oil-importing countries, which is 2.25 percent with the standard deviation of 2.14.

Moreover, evidence from **Table 2** reveals that the average value of oil price over the period is US\$64.55 per barrel. As may be observed from **Figs. 1** and **2**, oil price has experienced some positive and negative strikes in the period under study including the rising trend in 2000 through 2008 due to strike action in Venezuela during 2002/2003, unrest in the oil producing region in Nigeria, and increase in global demand for oil that was engineered by industrialisation and investment boom in the emerging Asian economies (see Salisu and Oloko, 2015). There are also significant falling trends or negative shocks associated with the 2007/2008 global economic and financial crises and increased shale oil production, which caused crude oil price to fall from US\$112/barrel in June 2014 to US\$32/barrel in February 2016 (see Olofin et al., 2020).

**Figs. 1** and **2** also show that inflation rate of oil-exporting and oil-importing countries has followed a unique path under the study period. On the average, Nigeria has the highest inflation rate among the oil-exporting countries, followed by Russia. Both countries have a double-digit inflation rates of 12.11 percent and 10.44 percent, respectively. Besides Brazil, which has an average inflation rate of 6.36 percent, all other oil-exporting countries have average inflation rates below 4 percent level, with the lowest being Canada that has an average inflation rate of 1.93 percent (see **Table 2**). Meanwhile, India has the highest inflation rate among the oil-importing countries, with an average inflation rate of 6.43 percent. Other oil-importing countries have average inflation rates below 3 percent. Overall, the group descriptive statistics show that countries operating inflation targeting and floating regime have high inflation rates than countries operating non-inflation targeting and pegged exchange rate regime, on average. This is consistent for oil-importing and oil-exporting countries.

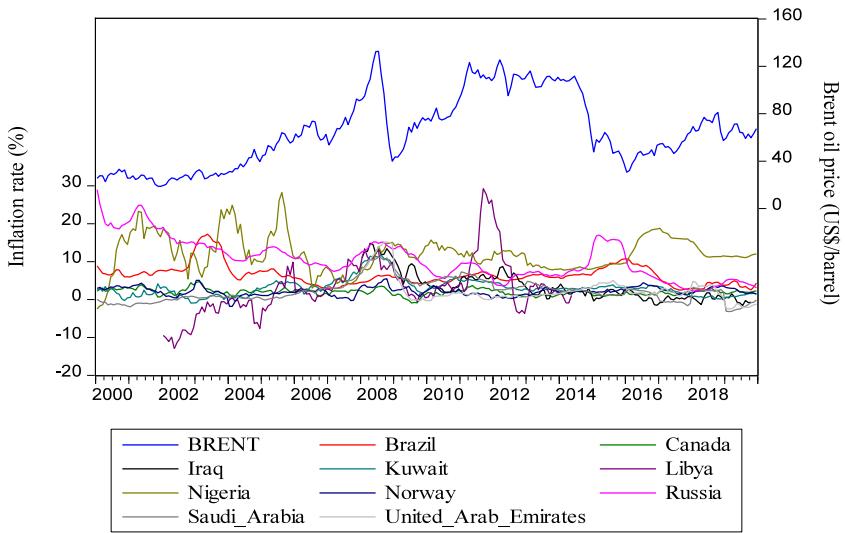


Fig. 1. Trends in oil price and inflation rate for oil-exporting countries.

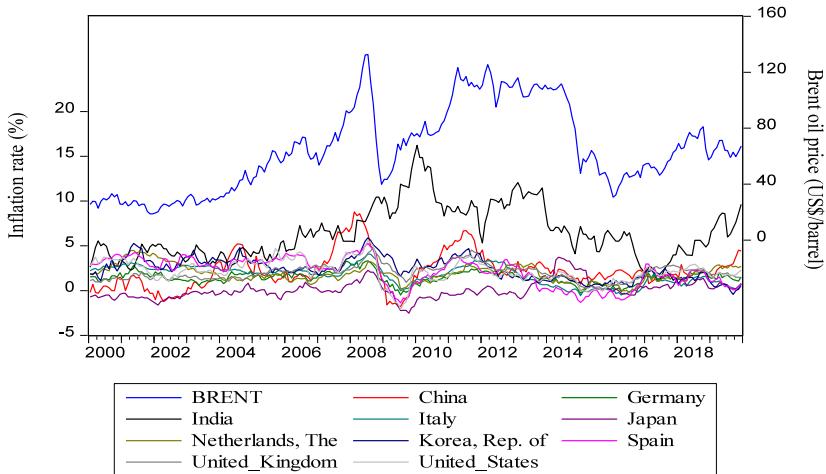


Fig. 2. Trends in oil price and inflation rate for oil-importing countries.

This suggests that inflation persistence may tend to be higher in countries operating inflation targeting and floating regime (Wu and Wu, 2018).

As a preliminary analysis, we test for the individual persistence of oil price and inflation rate of oil-exporting and oil-importing countries. We employ both autoregressive approach (as in (Gerlach and Tillmann, 2012; Granville and Zeng, 2019)) and fractional integration approaches (as in Canarella and Miller, 2016) to determine whether they are fractionally integrated. Persistence in oil price and inflation rate is measured under an autoregressive approach as the sum of autoregressive coefficients (see Gerlach and Tillmann, 2012), while it is measured by the degree of integration under the fractional integration approach. According to the autoregressive approach, inflation persistence can be adjudged to have long memory with permanent persistence (if the sum of autoregressive coefficients is not significantly different from 1) or short memory with temporary persistence (if the sum of the autoregressive coefficient is less than 1). However, the fractional integration approach also allows for intermediate situations of long memory with temporary persistence; hence, the name fractional integration.

In Table 3, the results of the persistence test on oil price and inflation rate for oil-exporting and oil-importing countries, using autoregressive and fractional integration approaches are presented. Under the autoregressive method, the null hypothesis of permanent inflation persistence (that is,  $\sum_{i=1}^p \beta_i = 1$ ) is significant for crude oil price and inflation rates of all oil-exporting and oil-importing countries. According to this approach, crude oil price and inflation rates of these countries have short memory or low persistence. In other words, shocks to these variables will die out exponentially within a short period (Granville and Zeng, 2019). This conclusion is reached because the persistence coefficients are

**Table 2**

Descriptive Statistics.

Source: Computed by the authors.

Oil Price/Inflation	Mean	Max.	Min.	S.Dev.	Skew.	Kurt.	J-B	Obs
Crude oil price								
Brent oil prices	64.554	132.720	18.710	29.973	0.388	2.070	14.671***	240
Oil-exporting countries								
Brazil	6.36	17.24	2.46	2.71	1.70	7.10	283.90***	240
Canada	1.93	4.68	-0.95	0.87	0.01	4.13	12.87***	240
Iraq	3.45	14.80	-1.61	3.83	1.17	3.72	35.48***	142
Kuwait	3.08	11.64	-0.99	2.37	1.47	6.07	180.89***	240
Libya	2.99	29.20	-13.01	7.45	0.93	5.01	46.35***	149
Nigeria	12.11	28.16	-2.49	4.81	0.26	3.93	11.52***	240
Norway	2.10	5.41	-1.83	1.11	-0.07	3.91	8.52***	240
Russia	10.44	28.93	2.20	5.37	0.69	3.11	19.17***	240
Saudi Arabia	2.18	11.08	-3.24	2.91	0.87	3.80	36.34***	240
UAE	2.38	15.09	-2.53	3.50	2.09	7.78	242.17***	144
Oil-importing countries								
China	2.24	8.80	-1.79	2.00	0.79	3.90	32.92***	240
Germany	1.46	3.32	-0.50	0.69	-0.03	3.47	2.28**	240
India	6.43	16.22	1.08	2.97	0.76	3.13	23.53***	240
Italy	1.72	4.08	-0.56	1.06	-0.24	2.14	9.67***	240
Japan	0.11	3.74	-2.52	1.02	1.01	5.13	85.65***	240
Netherlands	1.87	4.49	-0.24	0.97	0.45	2.98	7.98***	240
South Korea	2.42	5.90	-0.43	1.25	0.27	2.53	5.06***	240
Spain	2.10	5.27	-1.37	1.57	-0.46	2.20	14.93***	240
United Kingdom	2.00	4.79	0.20	0.87	0.51	3.46	12.39***	240
United States	2.17	5.60	-2.10	1.25	-0.34	3.76	10.46***	240
Group Descriptive Statistics								
<i>Oil Exporters</i>								
All	4.94	29.20	-13.01	5.27	1.22	5.07	899.90***	2115
Inflation targeting	5.21	28.93	-1.83	4.67	1.66	5.89	775.74***	960
Non-inflat. target	4.72	29.20	-13.01	5.71	1.03	4.55	321.08***	1155
<i>Oil Importers</i>								
All	2.25	16.22	-2.52	2.14	1.89	9.26	5346.02***	2400
Inflation targeting	2.25	16.22	-2.52	2.16	1.99	9.67	5427.14***	2160
Non-inflat. target	2.24	8.80	-1.79	2.00	0.79	3.90	32.92***	240

Note: Asterisks \*\*\*, \*\* and \* indicate 1%, 5% and 10% levels of statistical significance.

assumed to be significantly less than 1. Meanwhile, as may be observed, some of these coefficients are greater than 0.9. Some are even greater than 0.95, to the extent that we have a situation where inflation persistence is as high as 0.9743 (in the case of Saudi Arabia). This indicates that these variables are close to having long memory, and their classification as short memory variables may be wrong.

This assumption is verified using the fractional integration approach. Concerning the fractional integration results, the integration parameter for oil price and inflation rates of all oil-exporting and oil-importing countries is significantly different from 1, but not significantly different from 0.5. This implies that the oil price and the inflation rates of these countries are fractionally integrated. Thus, this justifies the application of fractional cointegration in this study. This is also consistent with the earlier studies suggesting that oil price and inflation rates are fractionally integrated (see [Gil-Alana and Gupta, 2014](#); [Granville and Zeng, 2019](#); [Tule et al., 2019](#); [Bilici and Çekin, 2020](#)).

#### 4. The model

Here, we provide a brief description of the method to be adopted in this study, drawing from two key studies that have proposed relevant methodologies to our study. These methods include: the conventional cointegration vector autoregressive [CVAR] model ([Johansen, 1995](#)) and the fractional cointegration vector autoregressive [FCVAR] model ([Johansen and Nielsen, 2012](#)). FCVAR has gained much popularity, as evident in its recent application in a variety of study areas ([Jones et al., 2014](#); [Gil-Alana and Carcel, 2018](#); [Nielsen and Shibaev, 2018](#); [Yaya et al., 2019, 2020](#); among others). We, comparatively, employ CVAR and FCVAR to examine the impacts of shocks to oil price on inflation persistence amidst diverse monetary policy frameworks and exchange rate regimes, by confirming if there exists a shared long-run relationship between the former and the latter, concerning some selected oil-exporting and oil-importing countries. By intuition, a confirmation of a cointegrating relationship between oil price and inflation rate would translate to the existence of a shared long-run relationship between both variables, such that a shock to any of the paired variables would impact on the other, and the shock will persist for a long time before fizzling out. Our interest here is majorly on the

**Table 3**

Results of persistence tests on oil price and inflation rate.

Source: Computed by the authors.

Oil Price/Inflation	Autoregressive approach		Fractional Integration approach		
	$\sum_{i=1}^p \beta_i(p)$	$\sum_{i=1}^p \beta_i = 1$	$d$ [se]	$d = 0.5$	$d = 1$
Brent oil price	0.9697**(2)	-0.0303***	0.4987*** [0.0148]	-0.0862	-33.9112***
Oil-exporting countries					
Brazil	0.9635***(2)	-0.0365***	0.4987***[0.0050]	-0.2531	-99.428***
Canada	0.8425***(3)	-0.1575***	0.4965***[0.0071]	-0.4952	-70.790***
Iraq	0.8811***(3)	-0.1189***	0.4973***[0.0154]	-0.1782	-32.739***
Kuwait	0.9638***(3)	-0.0362**	0.4985***[0.0030]	-0.4948	-165.630***
Libya	0.9325***(1)	-0.0675**	0.4970***[0.0226]	-0.1305	-22.220***
Nigeria	0.8871***(2)	-0.1129***	0.4971***[0.0077]	-0.3704	-65.273***
Norway	0.8591***(2)	-0.1409***	0.4978***[0.0177]	-0.1249	-28.417***
Russia	0.9658***(2)	-0.0341***	0.4990***[0.0077]	-0.1364	-65.474***
Saudi Arabia	0.9743***(2)	-0.0257*	0.4987***[0.0053]	-0.2523	-94.809***
UAE	0.9340***(3)	-0.0660***	0.4976***[0.0106]	-0.2265	-47.555***
Oil-importing countries					
China	0.9412***(3)	-0.0588***	0.4983***[ 0.0085]	-0.1984	-59.114***
Germany	0.8981***(3)	-0.1019***	0.4972***[ 0.0056]	-0.4899	-89.139***
India	0.9575***(3)	-0.0425**	0.4982***[ 0.0104]	-0.1749	-48.198***
Italy	0.9452***(3)	-0.0548***	0.4987***[0.0053]	-0.2464	-94.726***
Japan	0.9220***(2)	-0.0780***	0.4981***[0.0084]	-0.2218	-59.685***
Netherlands	0.9557***(1)	-0.0443**	0.4983***[0.0038]	-0.4445	-131.620***
South Korea	0.8960***(2)	-0.1040***	0.4979***[0.0046]	-0.4617	-110.241***
Spain	0.9291***(2)	-0.0709***	0.4984***[0.0061]	-0.2605	-82.905***
UK	0.9542***(3)	-0.0458***	0.4984***[0.0077]	-0.2008	-64.912***
USA	0.9105***(3)	-0.0895***	0.4979***[0.0052]	-0.4096	-96.012***

Note: Asterisks \*\*\*, \*\* and \* indicate 1%, 5% and 10% level of significance, respectively. Figures in square brackets represent the standard errors, while figures in round parenthesis indicate the optimal lag length for the autoregressive model, selected using Akaike Information Criterion (AIC) and the maximum lag of three (3). The traditional or autoregressive approach is defined as  $\pi_t = \alpha + \delta t + \sum_{i=1}^p \beta_i \pi_{t-i} + \varepsilon_t$ , where  $\pi_t$  is the inflation rate,  $t$  is trend,  $p$  is the optimal lag length and the sum of autoregressive coefficients,  $\sum_{i=1}^p \beta_i$ , measures the degree of persistence. The fractional parameter is estimated using the parametric method of Sowell (1992) which involves the maximum likelihood estimator. The test restrictions,  $\sum_{i=1}^p \beta_i = 1$  and  $d = 1$  are tests that inflation rates persist forever, while the test that  $d = 0.5$  tests that inflation is fractionally integrated. The restriction tests are conducted using Wald test restriction and t-statistic was reported in respect of test restrictions for  $d$ .

impact of shocks to oil price on inflation persistence. Also, the role of asymmetry in oil price in the oil price–inflation cointegrating relation is assessed.

We draw from the literature on studies that deviate from the convention of assuming integer-valued order of integration and describe briefly, the more flexible fractional variant<sup>4</sup> that allows for real-valued order of integration, whenever series are not integrated of order zero (Gil-Alana and Carcel, 2018). The latter provides researchers with evidence, whenever it exists, of plausible transitory, rather than the outright assumption of permanent nature of shocks that would require a long time to fizzle out. From the foregoing, we apply the fractional integration framework to inflation rates of developed and developing countries and global oil prices; and thus, specify a generic model in Eq. (1):

$$(1 - L)^d y_t = \alpha + \gamma \text{Trend} + \varepsilon_t \quad (1)$$

where  $y_t$  is the inflation rate or oil price;  $(1 - L)^d$  is a polynomial function of order  $d$  (a real-valued difference parameter);  $L$  is a lag operator, with  $L y_t$  indicating  $y_{t-1}$ ;  $\alpha$  is the model intercept and  $\gamma$  is a deterministic trend coefficient that allows for a more generalised determination of the fractional order; and  $\varepsilon_t \sim N(0, \sigma_\varepsilon^2)$ . A subset of the described model could also be specified by excluding the deterministic trend. For all real-valued  $d$ ,  $(1 - L)^d$  can be expanded using the binomial expansion and expressed as in Eq. (2), while the LHS of Eq. (1) is expressed in Eq. (3)

$$(1 - L)^d = \sum_{j=0}^{\infty} \binom{d}{j} (-1)^j L^j = 1 - dL + \frac{d(d-1)}{2} L^2 - \dots \quad (2)$$

$$\therefore (1 - L)^d y_t = y_t - dy_{t-1} + \frac{d(d-1)}{2} y_{t-2} - \dots \quad (3)$$

<sup>4</sup> See empirical studies such as Geweke and Porter-Hudak (1983); Dahlhaus (1989); Lo (1991); Sowell (1992); Robinson (1994, 1995a,b); Gil-Alana and Robinson (1997); Velasco (1999); Phillips and Shimosu (2004), Phillips and Shimotsu (2005); Abadir et al. (2007); Al-Shboul and Anwar (2016); Gil-Alana and Carcel (2018); Yaya et al. (2020). Others that apply fractional unit roots include Robinson (1994); Yaya et al. (2019); among others.

Therefore, Eq. (1) becomes:

$$z_t = \alpha + \gamma \text{Trend} + dy_{t-1} - \frac{d(d-1)}{2} y_{t-2} + \dots + \varepsilon_t \quad (4)$$

where  $d$  gives the degree of dependence of the series of interest that is relevant for market efficiency evaluation (see Gil-Alana and Carcel, 2018); while other parameters and variables are as previously defined.

Furthermore, we describe here the CVAR and FCVAR models, which are multivariate versions of the fractional integration method described earlier. We proceed with the specification of the CVAR model, before taking on the fractional variants - FCVAR model; since we consider the former as a benchmark model, and given that it formed the basis for the development of the latter. In this study, we define  $Z_t$  in four constructs depending on the model: the benchmark model  $Z_t = [inf_t \ mpr_t \ exc_t]'$ ; benchmark model with aggregate oil price  $Z_t = [inf_t \ mpr_t \ exc_t \ oil_t]'$ ; benchmark model with oil asymmetry  $Z_t = [inf_t \ mpr_t \ exc_t \ oil_t^{(-)} \ oil_t^{(+)}]'$  and benchmark model with negatively  $Z_t = [inf_t \ mpr_t \ exc_t \ oil_t^{(-)}]'$  and positively  $Z_t = [inf_t \ mpr_t \ exc_t \ oil_t^{(+)}]'$  decomposed partial sums of oil price; where the elements in the vector are  $I(d)$  series. The  $mpr$  is defined as interest rate for countries operating floating regime and inflation targeting monetary policy (IT & FR) and defined as external reserves for countries operating pegged regime and non-inflation targeting monetary policy (NIT & PR). The error correction form of Eq. (1) becomes equation (5), which is also specified with the lag operator as in Eq. (6):

$$\Delta Z_t = \alpha \beta' Z_{t-1} + \sum_{i=1}^k \Gamma_i \Delta Z_{t-i} + \varepsilon_t \quad (5)$$

$$\Delta Z_t = \alpha \beta' LZ_t + \sum_{i=1}^k \Gamma_i \Delta L^i Z_t + \varepsilon_t \quad (6)$$

Eq. (6) could be fractionally modified by incorporating a fractional difference operator and a fractional lag operator. This modification transforms the CVAR model to the FCVAR model. In other words, the difference and lag operators -  $\Delta$  and  $L$ , respectively, are replaced with the fractional difference and lag operators -  $\Delta^d$  and  $L_b = 1 - \Delta^b$ , respectively. Hence, the FCVAR specification in Eq. (7):

$$\Delta^d Z_t = \alpha \beta' \Delta^{d-b} L_b Z_t + \sum_{i=1}^k \Gamma_i \Delta^d L_b^i Z_t + \varepsilon_t \quad (7)$$

where  $\alpha$  and  $\beta$  are  $p \times r$  matrices (such that  $0 \leq r \leq p$ ) of long-run parameter estimates;  $r$  is the co-fractional or cointegration rank. The adjustment coefficients contained in matrix  $\alpha$  gives the speed of adjustment to equilibrium level, of each comprising variable. The  $r$  columns of matrix  $\beta$  gives the  $r$  cointegration vectors, with  $\beta' Z_t$  indicating the long-run equilibrium relations between/among variables in the system. The short-run dynamics of the variables in autoregressive augmentation are captured by  $\Gamma = (\Gamma_1, \dots, \Gamma_k)$  (see Nelson and Popiel, 2018). It is noteworthy to state here that FCVAR model becomes CVAR model if the relationship,  $d = b = 1$ , is confirmed. To account for asymmetric oil price effects, the crude oil price ( $oil_t$ ) is decomposed into positive and negative partial sums;  $oil_t^+ = \sum_{j=1}^t \Delta oil_j^+ = \sum_{j=1}^t \max(\Delta oil_j, 0)$  and  $oil_t^- = \sum_{j=1}^t \Delta oil_j^- = \sum_{j=1}^t \min(\Delta oil_j, 0)$ , respectively. Both are used to replace the aggregate oil price, to account for the asymmetric effect of oil price shock (see Salisu et al., 2019).

The procedure for the estimation is as follows: first, we confirm the fractional order ( $d$ ) of integration for the paired series; second, we determine the optimal lag length; third, we determine the cointegration rank based on the previously determined optimal lag length; fourth, we test for fractional cointegration using the optimal lag and cointegrating rank; and lastly, we employ the likelihood ratio [LR] statistic to compare FCVAR model with CVAR model, under the null hypothesis  $d = b = 1$ , where CVAR is preferred. Statistically significant likelihood ratio (LR) would indicate preference of FCVAR over CVAR, as the null hypothesis is rejected. Furthermore, the estimates of  $d$  obtained from separate estimation with positive and negative partial sums of oil price are also compared using the LR statistic, under the null of no asymmetry effect. Statistical significance here indicates evidence of asymmetry effect. Following the same procedure, we examine the effect of positive and negative oil price shocks separately by replacing aggregate oil price ( $oil_t$ ) with  $oil_t^+$  and  $oil_t^-$ , respectively, in separate models (see also Salisu et al., 2019).

Higher values of  $d$  are indicative of higher degrees of persistence that is inherent in the examined series and reflect the high dependence of current observations on the immediate past observations. A case of no dependence of current on immediate past observations implies that the series in question is stationary. Consequently, the estimated  $d$  could exhibit one of three plausible cases. When  $d = 0$ , the series is stationary or has short memory or is integrated of order zero; for  $0 < d < 0.5$ , the series exhibits long memory features with mean reversion and, thus, considered stationary; and for  $d \geq 0.5$ , the series has long memory and is non-stationary. Long memory that is characterised by non-stationarity may either show mean-reverting properties ( $0.5 < d < 1$ : transient impact of shocks) or non-mean-reverting properties ( $d \geq 1$ : permanent impact of shocks).

## 5. Results presentation and discussion

This section deals with the presentation and discussion of the empirical results of the study. It is sub-divided into four. The first sub-section deals with the analysis of the fractional cointegration among inflation rate, exchange rate and interest rate for inflation targeting and floating regime oil-exporting and oil-importing countries, and among inflation rate, exchange rate and external reserves for non-inflation targeting and pegged regime oil-exporting and oil-importing countries. This is used to determine the baseline inflation persistence of these countries under their respective monetary policy frameworks. This model was augmented to account for the effect of oil price shocks and possible asymmetry on inflation persistence, which is the main objective of this study. In the second sub-section, we discuss the results of the effect of oil price shocks on inflation persistence, without accounting for oil price asymmetry. In the third sub-section, we test and account for oil price asymmetry in the relationship, as failure to account for asymmetry, when it is significant may cause biased results (see for example Salisu et al., 2017, 2019; Akdogan, 2020; Raheem et al., 2020). In the fourth sub-section, a possible distinction between the effect of negative and positive oil price shocks on inflation persistence of the selected countries is examined.

### 5.1. Inflation persistence in the selected oil-exporting and oil-importing countries

The country and group results of inflation persistence for the selected oil-exporting and oil-importing countries are presented in Table 4. As evident in Table 4 (Panel A), the null hypothesis that CVAR is the preferred model cannot be rejected in the cointegration of inflation rate with other domestic factors for a few oil-exporting and some oil-importing countries. This suggests that CVAR could be used in modelling inflation persistence for these countries, particularly, when no external factor is being considered. For oil-exporting countries, two countries (Iraq and United Arab Emirates) have low inflation rate persistence (covariance stationary), while other countries have high inflation rate persistence (non-stationary). However, the inflation rate persistence of four countries (Canada, Libya, Nigeria, and Saudi Arabia), though high, is mean-reverting. This indicates that any domestic shocks to inflation rate will die out hyperbolically (Granville and Zeng, 2019). For the remaining four oil-exporting countries (Brazil, Kuwait, Norway, and Russia), their fractional integration coefficient is 1 and above. This suggests that any domestic shocks to inflation rate will persist permanently. For oil-importing countries, they all have high inflation persistence. However, three (3) countries (China, South Korea and USA) have mean-reverting, while the inflation rates of the other seven countries (Germany, India, Italy, Japan, Netherlands, Spain and UK) are not mean-reverting.

Overall, the result of inflation persistence for oil-exporting and oil-importing countries by group (see Table 4, Panel B) revealed that both oil-importing and oil-exporting countries have high but mean-reverting inflation persistence ( $0.5 < d < 1$ ), while oil-importing countries have higher inflation persistence than oil-exporting countries. This result appears to contradict our expectation that oil-importing countries with an averagely lower inflation rate will have lower inflation persistence. However, the variation may be because we account for the monetary policy framework and exchange rate regime of the countries in this study, which are ignored in some of the previous studies that found positive association between inflation rate and inflation persistence (see for example Meller and Nautz, 2012; Gerlach and Tillmann, 2012; Bratsiotis et al., 2015; Bilici and Çekin, 2020). The study also shows that inflation targeting & floating regime operating countries have higher inflation rate persistence than countries operating non-inflation targeting & pegged exchange rate regime for oil-exporting and oil-importing countries. This result supports evidence from Wu and Wu (2018), which found existence of higher inflation persistence under floating rates than under pegged rates. It, however, contradicts evidence from Bratsiotis et al. (2015) and Gerlach and Tillmann (2012) which stated that inflation persistence tends to decline, following the adoption of inflation targeting. This may suggest that exchange rate policy plays a stronger role than monetary policy in the determination of inflation rate persistence.

### 5.2. Oil price shock and inflation persistence

To examine the effect of oil price on inflation persistence of the selected oil-exporting and oil-importing countries, our baseline model is augmented with crude oil price. This serves as the countries' inflation rate persistence after accounting for the role of external factor, which has been ignored in the previous literature on inflation persistence. The result of the relationship between oil price and inflation persistence by individual countries and by group is presented in Table 5 (Panel A and B). This is evaluated mainly by change in inflation persistence of countries as a result of oil price shock ( $d_1 - d_0$ ). As evident, the likelihood ratio (LR) comparing the CVAR and FCVAR models overly favours the FCVAR model; thus, confirming the appropriateness of the choice of FCVAR in modelling the relationship between oil price shock and inflation persistence in this study.

In Table 5 (Panel A), the result shows that oil price shock reduces inflation persistence of some oil-importing and oil-exporting countries, while few countries (mainly oil exporters) experienced higher inflation persistence due to oil price shock. Specifically, the inflation persistence of three (3) oil-exporting countries (Brazil, Kuwait and Norway) reduced from permanent persistence to long memory temporary persistence, the inflation persistence of the UAE increased from short persistence to long memory temporary persistence, while the stances inflation persistence of the other six (6) oil exporters (Canada, Iraq, Libya, Nigeria, Russia and Saudi Arabia) do not change significantly. This implies that the monetary

**Table 4**

Inflation persistence by country and group of countries.

Source: Computed by the authors.

Countries	<i>k</i>	<i>r</i>	$d_0$ [s.e]	95% Confidence Interval	FCVAR vs. CVAR
Panel A: Inflation persistence by country					
Oil-exporting countries					
Brazil	2	1	0.973 [0.052]	(0.871, 1.075)	0.265
Canada	1	1	0.615 [0.030]	(0.556, 0.674)	26.316***
Iraq	2	2	0.376 [0.010]	(0.356, 0.396)	11.383***
Kuwait	2	1	0.987 [0.032]	(0.924, 1.050)	0.046
Libya	1	1	0.530 [0.020]	(0.491, 0.569)	18.321***
Nigeria	1	1	0.726 [0.036]	(0.655, 0.797)	9.452***
Norway	2	1	0.926 [0.047]	(0.834, 1.018)	2.178
Russia	2	1	1.091 [0.043]	(1.007, 1.175)	4.630**
Saudi Arabia	1	1	0.646 [0.018]	(0.611, 0.681)	34.517***
UAE	2	1	0.154 [0.004]	(0.146, 0.162)	27.885***
Oil-importing countries					
China	2	1	0.667 [0.030]	(0.608, 0.726)	30.045***
Germany	2	1	0.946 [0.047]	(0.854, 1.038)	1.283
India	2	1	0.970 [0.045]	(0.882, 1.058)	0.441
Italy	2	1	0.964 [0.060]	(0.846, 1.082)	0.347
Japan	1	1	0.938 [0.074]	(0.793, 1.083)	0.684
Netherlands	2	1	0.958 [0.060]	(0.840, 1.076)	0.499
South Korea	2	1	0.674 [0.031]	(0.613, 0.735)	19.314***
Spain	2	1	0.933 [0.058]	(0.819, 1.047)	1.341
UK	1	1	1.213 [0.040]	(1.135, 1.291)	21.065***
USA	2	1	0.880 [0.066]	(0.751, 1.009)	2.870*
Panel B: Inflation persistence by group					
Countries	$d_0$ [se]	95% Confidence interval	Wald Test		
			$d_0 = 0.5$	$d_0 = 1$	
Oil exporters					
All	0.702 [0.094]	(0.517, 0.888)	2.142**	-3.149***	
IT& FR	0.901 [0.102]	(0.702, 1.100)	3.952***	-0.973	
NIT&PR	0.570 [0.118]	(0.339, 0.801)	0.593	-3.652***	
Oil importers					
All	0.914 [0.049]	(0.818, 1.011)	8.405***	-1.739*	
IT& FR	0.942 [0.046]	(0.852, 1.031)	9.655***	-1.272	
NIT&PR	0.667 [0.030]	(0.608, 0.726)	5.567***	-11.1***	

Note: Figures in square bracket "[]" indicates standard errors, while asterisks, \*\*\*, \*\* and \* represent rejection of the null hypothesis at 1%, 5% and 10%, respectively. In addition, *d* is the order of inflation persistence, *k* indicates the number of optimal lags, while *r* is the chosen rank. The  $d_0$  indicates inflation persistence from the baseline model, while test restrictions  $d_0 = 0.5$  and  $d_0 = 1$  are used to assess the degree and significance of the group inflation persistence.

policy of the three countries whose inflation persistence reduced and the six countries whose inflation persistence do not change significantly, accommodate oil price shock and may not necessarily be changed due to oil price shock. For the UAE, the efficiency of the country's monetary policy appears to reduce in the face of oil price shock; hence, the country may consider a review of its monetary policy in the face of oil price shock.

For oil-importing countries, the inflation persistence of six countries (Germany, India, Italy, Japan, Netherlands and Spain) reduced from permanent persistence to long memory temporary persistence. The inflation persistence of China reduced from long memory temporary persistence to short persistence, while the inflation persistence of the other three countries (South Korea, UK and USA) do not change significantly. As the inflation persistence of oil-importing countries do not appear to increase due to oil price shock, it suggests that their monetary policy accommodates oil price shock and may not necessarily be changed due to oil price shock. According to Bernanke et al. (1997), Kormilitsina (2011) and Olubusoye et al. (2015), altering monetary policy in the face of oil price shock, when it is not necessary to do so, may have long-run adverse effect on the economy.

Overall, the group inflation persistence (in Table 5, Panel B) shows that inflation persistence of oil-importing countries is relatively higher than that of oil-exporting countries, although, both are non-stationary mean-reverting. This suggests that the effect of oil price shocks on inflation rate of oil-exporting and oil-importing will die out after a long time, but will die out in oil-exporting before oil-importing countries. This is consistent with the result of Salisu et al. (2017), which finds that oil price exerts a greater impact on inflation of net oil-importing countries than their oil-exporting counterparts in the long-run, as higher inflation rate may be expected to translate to higher inflation rate persistence.

Similarly, the fairly similar persistence result for oil-importing and oil-exporting countries can be related to the finding by Salisu et al. (2017), which revealed that oil price shock has similar long-run effect on the inflation rates

**Table 5**

Oil price shock and inflation persistence.

Source: Computed by the authors.

Countries	<i>k</i>	<i>r</i>	$d_1$ [ <i>s.e</i> ]	95% Conf. Inter.	FCVAR vs. CVAR	$d_1 - d_0$
Panel A: Oil price shock and inflation persistence by country						
Oil-exporting countries						
Brazil	2	1	0.907 [0.057]	(0.795, 1.019)	3.024*	<b>-0.066</b>
Canada	1	1	0.667 [0.031]	(0.606, 0.728)	38.848***	0.052
Iraq	2	2	0.072 [0.001]	(0.070, 0.074)	32.898***	-0.304
Kuwait	2	1	0.843 [0.019]	(0.806, 0.880)	6.234**	<b>-0.144</b>
Libya	1	1	0.576 [0.025]	(0.527, 0.625)	30.961***	0.046
Nigeria	1	1	0.734 [0.030]	(0.675, 0.793)	16.297***	0.008
Norway	2	1	0.897 [0.039]	(0.821, 0.973)	6.177**	<b>-0.029</b>
Russia	2	1	1.067 [0.040]	(0.989, 1.145)	2.868*	-0.024
Saudi Arabia	1	1	0.617 [0.018]	(0.582, 0.652)	57.120***	-0.029
UAE	2	1	0.589 [0.038]	(0.515, 0.663)	18.313***	<b>0.435</b>
Oil-importing countries						
China	2	1	0.406 [0.016]	(0.375, 0.437)	45.132***	<b>-0.261</b>
Germany	2	1	0.896 [0.042]	(0.814, 0.978)	6.030**	<b>-0.050</b>
India	2	1	0.938 [0.043]	(0.854, 1.022)	2.055	<b>-0.032</b>
Italy	2	1	0.878 [0.045]	(0.790, 0.966)	6.591**	<b>-0.086</b>
Japan	1	1	0.825 [0.055]	(0.717, 0.933)	7.091***	<b>-0.113</b>
Netherlands	2	1	0.910 [0.049]	(0.814, 1.006)	3.502*	<b>-0.048</b>
South Korea	2	1	0.793 [0.031]	(0.732, 0.854)	10.138***	0.119
Spain	2	1	0.899 [0.044]	(0.813, 0.985)	5.012**	<b>-0.034</b>
UK	1	1	1.166 [0.040]	(1.088, 1.244)	9.328***	-0.047
USA	2	1	0.864 [0.059]	(0.748, 0.980)	5.686**	-0.016
Panel B: Oil price shock and inflation persistence by group						
Countries	$d_0$ [ <i>s.e</i> ]	95% Conf. inter.	Wald Test			
			$d_1 = 0.5$	$d_1 = 1$	$d_1 - d_0 = 0$	
Oil exporters						
All	0.697 [0.086]	(0.528, 0.866)	2.286**	-3.518***	-0.030	
IT& FR	0.885 [0.082]	(0.723, 1.046)	4.672***	-1.403	-0.091	
NIT&PR	0.572 [0.108]	(0.360, 0.784)	0.663	-3.953***	0.009	
Oil importers						
All	0.858 [0.059]	(0.741, 0.974)	6.022***	-2.401**	-0.523	
IT& FR	0.908 [0.035]	(0.838, 0.977)	11.490***	-2.602***	-0.420	
NIT&PR	0.406 [0.016]	(0.375, 0.437)	-5.875***	-37.125***	-5.674***	

Note: Figures in square bracket "[]" indicates standard errors, while asterisks, \*\*\*, \*\* and \* represent rejection of the null hypothesis at 1%, 5% and 10%, respectively. In addition,  $d$  is the order of inflation persistence,  $k$  indicates the number of optimal lags, while  $r$  is the chosen rank. The  $d_0$  indicates inflation persistence from the baseline model and  $d_1$  is the inflation persistence from augmented model with oil price. The test restrictions  $d_1 = 0.5$  and  $d_1 = 1$  are used to assess the degree and significance of the group inflation persistence, while  $d_1 - d_0 = 0$  is used to test the significance of the deviation in inflation persistence due to oil price shock from the baseline persistence.

of both oil-exporting and oil-importing countries. More so, the results show that countries operating floating regime with inflation targeting (IT&FR) have higher inflation persistence than countries operating pegged exchange rate regime with non-inflation targeting monetary policy (NIT&PR). This result is also consistent for oil-exporting and oil-importing countries. It partially supports the evidence from Wu and Wu (2018), which found existence of higher inflation persistence under floating rates than under pegged rates. Meanwhile, as recent studies (Nusair, 2019; Akinsola and Odhiambo, 2020; Raheem et al., 2020) revealed that domestic economic indicators, such as inflation respond asymmetrically to changes in international commodity prices (oil), we account for the role of oil price asymmetry to avoid reporting misleading results. This is considered in the following sub-section.

### 5.3. Oil price asymmetry and inflation rate persistence

**Table 6** presents the results of the test for oil price asymmetry in modelling the effect of oil price shock on inflation persistence oil-exporting and oil-importing countries, while **Table 7** presents the revised results for oil price–inflation persistence relationship after accounting for oil price asymmetry. As evident from **Table 6**, the log-likelihood ratio (LR) statistics comparing the baseline model that is augmented with positive oil price shock and the baseline model that is augmented with negative oil price shock revealed that the two models are significantly different. This indicates that the effects of positive and negative oil price shocks are statistically significant (significantly different). The significance of asymmetries in oil price dynamics is supportive of the argument by Nusair (2019), Akinsola and Odhiambo (2020) and (Raheem et al., 2020), which revealed that inflation responds asymmetrically to changes in international commodity

**Table 6**

Inflation persistence and Oil price asymmetric.

Source: Computed by the authors.

Countries	<i>k</i>	<i>r</i>	<i>d</i> <sup>+</sup>	<i>d</i> <sup>-</sup>	<i>d</i> <sup>+</sup> vs. <i>d</i> <sup>-</sup>
<i>Oil-exporting countries</i>					
Brazil	2	1	0.5200[0.0490]	1.0380[0.0560]	-95.320***
Canada	1	1	0.5350[0.0220]	0.6380[0.0270]	-64.060***
Iraq	2	2	0.0180[0.0000]	0.3030[0.0040]	-59.666***
Kuwait	2	1	0.3520[0.0250]	0.5470[0.0350]	-99.421***
Libya	1	1	0.5230[0.0240]	0.6980[0.0480]	-38.594***
Nigeria	1	1	0.5980[0.0230]	0.7460[0.0280]	-88.789***
Norway	2	1	0.8880[0.0380]	0.7030[0.0560]	-38.574***
Russia	2	1	0.6200[0.0330]	0.6550[0.0410]	-92.045***
Saudi Arabia	1	1	0.6140[0.0190]	0.6760[0.0250]	-83.256***
UAE	2	1	0.1330[0.0030]	0.2050[0.0050]	-99.981***
<i>Oil-importing countries</i>					
China	2	1	0.3620[0.0130]	0.4150[0.0150]	-108.835***
Germany	2	1	0.3240[0.0250]	1.0220[0.0460]	-66.688***
India	2	1	0.7760[0.0440]	0.9590[0.0520]	-62.552***
Italy	2	1	0.3070[0.0210]	1.0500[0.0470]	-65.397***
Japan	1	1	0.6760[0.0270]	0.8120[0.0790]	-54.487***
Netherlands	2	1	0.3500[0.0260]	1.0250[0.0420]	-71.061***
South Korea	2	1	0.5600[0.0260]	0.5040[0.0250]	-52.086***
Spain	2	1	0.3280[0.0230]	1.0430[0.0450]	-69.723***
UK	1	1	0.5430[0.0200]	0.6990[0.0400]	-56.561***
USA	2	1	0.5150[0.0450]	0.4930[0.0320]	-43.516***

Note: Figures in squared bracket “[]” indicates standard errors, while asterisks, \*\*\* \*\* and \* represent rejection of the null hypothesis that degree of oil price–inflation rate cointegrating persistence with positive oil price shock (*d*<sup>+</sup>) is insignificantly different from degree of oil price–inflation rate cointegrating persistence with negative oil price shock (*d*<sup>-</sup>). More so, *k* indicates the number of optimal lags, while *r* is the number of cointegrating equation.

prices. According to these studies, failure to account for oil price asymmetry when it is significant may generate misleading results.

Thus, we account for oil price asymmetry in our model by augmenting the baseline model with the disaggregated oil price (positive and negative oil price shocks). The results are presented in Table 7. Comparing this result with those of the model without asymmetry (in Table 5), we find that the degree of inflation persistence is lower for virtually all the oil-exporting and oil-importing countries (excl. Germany), after accounting for asymmetry in oil price dynamics. This suggests that inflation persistence may be exaggerated without accounting for oil price asymmetry. Nonetheless, some results from the model without asymmetry are confirmed by those of the model with oil price asymmetry. For the oil-exporting countries, the results that inflation persistence in the face of oil price shock for Brazil, Kuwait and Norway reduced and that for Canada, Iraq, Libya, Nigeria, and Saudi Arabia do not change significantly, are confirmed. The inflation persistence of UAE in the face of oil price shock was, however, shown to be exaggerated, while that of Russia was shown to be underestimated.

For the oil-importing countries, the results of the effect of oil price shock on inflation persistence are confirmed for seven countries but exaggerated for Germany, US and UK. Exaggeration or under-estimation of oil price–inflation persistence constitutes biased results; thus, supporting the argument by Akdoğan (2020), Salisu et al. (2017, 2019) that failure to account for significant asymmetric effect may lead to inefficient results. Notably, however, the misconception of the oil price–inflation persistence of a country due to misleading results may cause the introduction of inappropriate economic stabilisation policies; thus, invoking undesirable effects on the economy (see Bernanke et al., 1997; Kormiltsina, 2011).

Table 7 (Panel B) summarises the results of the effect of oil price shock on inflation persistence of oil-exporting and oil-importing countries after accounting for oil price asymmetry. Generally, the result shows that inflation persistence of oil-importing countries is relatively higher than that of oil-exporting countries, although both are non-stationary but mean-reverting ( $0.5 < d < 1$ ). This is similar to the result obtained without accounting for oil price asymmetry but does not mean that accounting for asymmetry can be ignored. The result also shows that countries operating floating regime with inflation targeting (IT&FR) have higher inflation persistence than countries operating pegged exchange rate regime with non-inflation targeting monetary policy (NIT&PR). This result is also consistent with the result for oil price–inflation persistence with accounting for oil price asymmetry. It partially supports the evidence from Wu and Wu (2018), which finds existence of higher inflation persistence under floating rates than under pegged rates. Meanwhile, the result reveals that oil-importing countries operating non-inflation targeting monetary policy (NIT&PR), like China, tends to have short memory inflation persistence ( $d < 0.5$ ) unlike their oil-exporting counterparts (such as Saudi Arabia, Iraq, Kuwait, Nigeria, Libya and UAE) that have long memory temporary inflation persistence ( $0.5 \leq d < 1$ ).

**Table 7**

Asymmetric oil price shock and inflation persistence.

Source: Computed by the authors.

Countries	<i>k</i>	<i>r</i>	$d_2[se]$	95% Confidence Interval	FCVAR vs. CVAR	$d_2 - d_0$
Panel A: Asymmetric oil price shock and inflation persistence by country						
Oil-exporting countries						
Brazil	2	1	0.450[0.048]	(0.356, 0.544)	48.406***	-0.523
Canada	1	1	0.612[0.020]	(0.573, 0.651)	55.556***	-0.003
Iraq	2	2	0.013[0.000]	(0.013, 0.013)	73.844***	-0.363
Kuwait	2	1	0.596[0.023]	(0.551, 0.641)	84.297***	-0.391
Libya	1	1	0.544[0.017]	(0.511, 0.577)	30.199***	0.014
Nigeria	1	1	0.695[0.012]	(0.671, 0.719)	16.342***	-0.031
Norway	2	1	0.699[0.032]	(0.636, 0.762)	39.094***	-0.227
Russia	2	1	0.625[0.030]	(0.566, 0.684)	60.119***	-0.466
Saudi Arabia	1	1	0.602[0.019]	(0.565, 0.639)	121.508***	-0.044
UAE	2	1	0.223[0.006]	(0.211, 0.235)	73.717***	0.069
Oil-importing countries						
China	2	1	0.355[0.010]	(0.335, 0.375)	81.105***	-0.312
Germany	2	1	0.925[0.035]	(0.856, 0.994)	2.555	-0.021
India	2	1	0.726[0.037]	(0.653, 0.799)	36.117***	-0.244
Italy	2	1	0.747[0.036]	(0.676, 0.818)	37.176***	-0.217
Japan	1	1	0.681[0.024]	(0.634, 0.728)	58.459***	-0.257
Netherlands	2	1	0.414[0.036]	(0.343, 0.485)	57.329***	-0.544
South Korea	2	1	0.562[0.029]	(0.505, 0.619)	67.342***	-0.112
Spain	2	1	0.349[0.024]	(0.302, 0.396)	58.130***	-0.584
UK	1	1	0.561[0.022]	(0.518, 0.604)	8.659***	-0.652
USA	2	1	0.463[0.040]	(0.385, 0.541)	68.285***	-0.417
Panel B: Oil price shock and inflation persistence by group						
Countries	$d_2[se]$	95% Confidence interval	Wald Test			
			$d_2 = 0.5$	$d_2 = 1$	$d_2 - d_0 = 0$	
Oil exporters						
All	0.506 [0.070]	(0.368, 0.643)	0.084	-7.039***	-1.193	
IT& FR	0.597 [0.052]	(0.494, 0.699)	1.840*	-7.692***	-1.979**	
NIT&PR	0.446 [0.109]	(0.232, 0.659)	-0.501	-5.093***	-0.548	
Oil importers						
All	0.578 [0.060]	(0.461, 0.696)	1.304	-7.025***	-3.073***	
IT& FR	0.603 [0.061]	(0.483, 0.723)	1.687*	-6.494***	-3.169***	
NIT&PR	0.355 [0.010]	(0.335, 0.375)	-14.500***	-64.500***	-7.800***	

Note: Figures in square bracket "[]" indicates standard errors, while asterisks, \*\*\*, \*\* and \* represent rejection of the null hypothesis at 1%, 5% and 10%, respectively. In addition, *d* is the order of inflation persistence, *k* indicates the number of optimal lags, while *r* is the chosen rank. The  $d_0$  indicates inflation persistence from the baseline model and  $d_2$  is the inflation persistence from augmented model with asymmetric oil price. The test restrictions  $d_2 = 0.5$  and  $d_2 = 1$  are used to assess the degree and significance of the group inflation persistence, while  $d_2 - d_0 = 0$  is used to test the significance of the deviation in inflation persistence due to oil price shock from the baseline persistence.

#### 5.4. Positive and negative oil price shocks and inflation persistence

We examine the possible distinction between the effects of positive and negative oil price shocks on inflation persistence of oil-importing and oil-exporting countries. The results are presented in Table 8. The results show that positive and negative oil price shocks do not have significant impact on inflation persistence of oil-exporting countries. This is consistent for floating regime and inflation targeting countries, as well as countries operating pegged exchange rate regime and non-inflation targeting. This suggests that the monetary policy operated by these countries fairly accommodates negative and positive oil price shocks. Hence, no monetary policy change is required in the face of positive and negative oil price shocks. Similar results were obtained for oil-importing countries, which show significantly lower inflation persistence, particularly, in the face of positive oil price shock. This indicates that the monetary policy of oil-importing countries better accommodates positive and negative oil price shocks and do not need to be changed in the face of positive and negative oil price shocks. Hence, there is no technical distinction between the impact of negative and positive oil price shocks on inflation persistence of oil-exporting and oil-importing countries.

#### 6. Conclusion

Instituting monetary policy in reaction to oil price shock when the oil price shock does not constitute a threat to the economy has been explained to have adverse long-run effect on the economy (Bernanke et al., 1997; Kormilitsina, 2011). This study investigates oil price–inflation persistence relationship to analyse the effect of oil price shocks on

**Table 8**

Results of positive and negative oil price shocks and inflation persistence.

Source: Computed by the authors.

Status	Negative Oil Asymmetry				Positive Oil Asymmetry			
	$d^{(-)}$	Wald Test			$d^{(+)}$	Wald Test		
		$d^{(-)} = 0.5$	$d^{(-)} = 1$	$d^{(-)} - d_0 = 0$		$d^{(+) = 0.5}$	$d^{(+) = 1}$	$d^{(+) - d_0 = 0}$
<i>Oil Exporters</i>								
All	0.621 [0.074] (0.477, 0.765)	1.645	-5.157***	-0.485	0.480 [0.080] (0.323, 0.637)	-0.249	-6.506***	-1.275
Inflation Targeting	0.759 [0.094] (0.574, 0.943)	2.745***	-2.564**	-0.729	0.641 [0.085] (0.474, 0.808)	1.650*	-4.211***	-1.394
Non Inflation Targeting	0.529 [0.092] (0.349, 0.709)	0.317	-5.121***	-0.194	0.373 [0.103] (0.172, 0.574)	-1.239	-6.116***	-0.893
<i>Oil Importers</i>								
All	0.802 [0.081] (0.644, 0.961)	3.742***	-2.449**	-0.862	0.474 [0.052] (0.372, 0.576)	-0.496	-10.070***	-4.336***
Inflation Targeting	0.845 [0.076] (0.695, 0.995)	4.517***	-2.025**	-0.790	0.487 [0.057] (0.375, 0.598)	-0.237	-9.055***	-4.443***
Non Inflation Targeting	0.415 [0.015] (0.386, 0.444)	-5.667***	-39.000***	-5.600***	0.362 [0.013] (0.337, 0.387)	-10.615***	-49.077***	-7.093***

Note: Figures in square bracket "[]" indicate standard errors, figures in round bracket "(") indicate confidence intervals, while asterisks, \*\*\*, \*\* and \* represent rejection of the null hypothesis at 1%, 5% and 10%, respectively. In addition,  $d_0$  indicates inflation persistence from the baseline model and  $d^{(*)}$  is the inflation persistence from augmented model with asymmetric oil price. The test restrictions  $d^{(*)} = 0.5$  and  $d^{(*)} = 1$  are used to assess the degree and significance of the group inflation persistence, while  $d^{(*)} - d_0 = 0$  is used to test the significance of the deviation in inflation persistence from the baseline due to either positive or negative oil price shock.

inflation persistence of top ten (10) oil-exporting and oil-importing countries. It contributes to literature on the analysis of the degrees and determinants of inflation persistence of selected countries in three major ways. First, it examined the effect of an external factor, oil price, on inflation persistence of oil-exporting and oil-importing countries using fractional cointegration vector autoregressive (FCVAR) model by Johansen (1996). Second, it accounts for the role of monetary policy framework and exchange rate regime in modelling the effect of oil price shocks on inflation persistence of the selected countries. Third, it tests and accounts for the asymmetric nature of oil price, which has been widely documented in the literature.

The likelihood ratio (LR) test comparing the CVAR and FCVAR for the inflation persistence models that have been augmented with oil price overly favours the FCVAR model. This confirms the appropriateness of the choice of FCVAR in modelling the relationship between oil price shock and inflation persistence in this study. Evidently, the main results of this study show that inflation persistence of oil-exporting and oil-importing countries do not appear to increase due to oil price shocks, suggesting that the monetary policies of these countries accommodates oil price shocks, and may not necessarily be changed due to oil price shocks. Even as failure to account for oil price asymmetry tends to exaggerate inflation persistence for oil-exporting and oil-importing countries, the conclusion does not change markedly. This result is also consistent after accounting for oil price asymmetry, under positive and negative oil price shocks. This result is consistent with Bernanke et al. (1997), Kormilitsina (2011) and Olubusoye et al. (2015) which suggests that monetary policy may not necessarily be changed due to oil price shocks.

Furthermore, we find that inflation persistence of oil-importing countries is relatively higher than that of oil-exporting countries, although both are non-stationary but mean-reverting. This suggests that the effect of oil price shocks on inflation rate of oil-exporting and oil-importing will die out after a long time, but faster in oil-exporting than oil-importing countries. This is consistent with result of Salisu et al. (2017), which shows that oil price exerts a greater impact on the inflation of net oil-importing countries than their oil-exporting counterparts in the long-run, as higher inflation rate may be expected to translate to higher inflation rate persistence. Our results also show that countries operating floating regime with inflation targeting (IT&FR) have higher inflation persistence than countries operating pegged exchange rate regime with non-inflation targeting monetary policy (NIT&PR). This is consistent for oil-importing and oil-exporting countries. More so, it partly supports the evidence from Wu and Wu (2018), which finds the existence of higher inflation persistence under floating rates than under pegged rates. Meanwhile, we also found that oil-importing countries operating non-inflation targeting monetary policy (NIT&PR) like China tend to have short memory inflation persistence ( $d < 0.5$ ), unlike their oil-exporting counterparts (such as Saudi Arabia, Iraq, Kuwait, Nigeria, Libya, and UAE) which tend to have long memory temporary inflation persistence ( $0.5 \leq d < 1$ ).

## Declaration of competing interest

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

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