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## Article

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## Research paper

## Asymmetric effect of oil price on economic growth: Panel analysis of low-income oil-importing countries

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## ABSTRACT

This paper examines the impact of oil price on economic growth in seven low-income oil-importing sub-Saharan African (SSA) countries, namely Ethiopia, Gambia, Mali, Mozambique, Senegal, Tanzania and Uganda. Using panel-Auto Regressive Distributive Lag (panel-ARDL), we examined the impact of oil price on economic growth in the short and long run. The results show that oil price does not have a significant impact on economic growth in the short run for the group, but has a negative significant impact in the long run. However, the short-run country coefficients show that oil price has a significant but mixed effect on economic growth in all the seven countries. Using the Non-linear Autoregressive Distributed Lag (NARDL) model, we also examined the asymmetric effect of oil price on economic growth by decomposing oil price into negative and positive changes. The advantage of this model is that it examines both the long-run and short-run asymmetric effects of real oil price on growth. We found that a decrease in oil price has a positive and significant impact on growth, while oil price increase has a significant negative effect. Moreover, the error correction terms are negative and statistically significant for both the PMG and five of the countries in the short-run country coefficients. Therefore, it would be important for policymakers to explore and implement efficient energy policies and employ technological advancement policies to mitigate oil price risks, especially in the long run.

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## 1. Introduction

Fluctuations in oil prices have been established as a major cause of economic crises and negative economic growth. The impact of oil price on economic growth, however, is divergent in the literature (Hamilton, 1983, 1996; Darby, 1982; Blanchard and Gali, 2007; Jiménez-Rodríguez and Sánchez, 2005). Although a substantial number of studies analyse the impact of oil prices on economic growth, most focused on Asia, Latin America, developed countries and Arab countries. Examples include studies by Cunado and Perez-de Gracia (2003, 2005), which focused on several European and Asian countries respectively. Lescaroux and Mignon (2008) investigated a large group of countries, including both importing and exporting countries, and Du and Wei (2010) investigated China's economy. Hanabusa (2009) focused on the Japanese economy, Jiménez-Rodríguez and Sánchez (2005) provided empirical evidence for some OECD countries, while Berument, Ceylan and Dogan (2010) examined countries in the Middle East and North Africa (MENA) region. The effect of sharp changes in oil price depends on whether a country is an

importer or an exporter of oil. Since oil is input in the production process, a rise in the price of oil increases the production costs for an oil importer, leading to cost-push inflation and lower economic growth (Mordi and Adebisi, 2010; Sauter and Awerbuch, 2003). The impact of oil price changes on oil-importing nations is twofold. Firstly, a fall in oil price is beneficial to oil-importing countries, as the balance of payments and terms of trade tend to increase. Secondly, a rise in oil price may cause a steep drop in income, especially for the countries whose economies are highly dependent on oil (Deaton, 1999). Theoretical explanation of the relationship between oil price and economic growth emphasised both the demand and supply-side effects. From the demand side, a fall in oil prices generates a rise in disposable income of an oil-importing country, leading to an increase in the demand for other commodities, especially those with high-income elasticity. A decrease in oil prices, however, has an impact on other energy products, such as coal, gas, and electricity. From the supply side, oil is a production input for many commodities, such as electricity and transportation. An increase in oil prices will lead to an increase in production costs and prices of other commodities. Therefore, oil price fluctuation may affect the prices of other commodities and thus plays a key role in its relationship with GDP growth (Lescaroux and Mignon, 2008; Odhiambo, 2010).

Research on the impact of oil prices on economic growth has been growing since the oil price crisis of 1985/86. However, little

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research has been done on low-income oil-importing SSA countries. Bacon and Mattar (2005) estimated that, compared to the highest income group, the effect of oil price shocks on developing countries could be twice as hard. Moreover, SSA consists mostly of low-income and middle-income countries. The magnitude of the impact of oil price volatility on economic growth, however, depends on the distribution of oil imports across oil-importing countries and portfolio preferences of both oil-importing and oil-exporting countries (Huang and Guo, 2007; Fowowe, 2014). Another study by Bacon (2005) calculated the impacts of a continuous increase of US\$10 per barrel in oil price for 131 countries. The author found that countries with less than US\$300 per capita income experienced the highest percentage decrease in GDP than other income groups in the study. Low-income countries (LICs) in SSA have similar characteristics in terms of energy sources and use, and the demand for oil is growing, especially for transport and electricity generation. According to the British Petroleum (B.P.) (2018), growth in oil consumption has been on the increase since 2008. Excluding major consumer countries such as Algeria, Egypt, Morocco, Nigeria and South Africa, African countries consumed 1.762 m barrels of oil per day in 2015, 1.833 m in 2016, 1.958 m in 2017 and 1.996 m in 2018. This, therefore, necessitates the investigation of the impact of oil price on growth in LIC. Figs. 1 and 2 show world consumption rates from 2008 to 2018, and regional consumption of different sources of fuel in 2018, respectively.

Fig. 1 shows that oil remains the major global source of fuel and energy consumption, followed by coal. The regional consumption by energy sources indicated in Fig. 2 also shows that oil represents the highest proportion of energy consumption in 2018 across all regions except the Commonwealth of Independent States (CIS).

Moreover, recent studies have emphasised the role of asymmetric effect in the literature. Mork (1989) and Mory (1993) argued that oil price has an asymmetric effect and needs to be decomposed into oil price increase and decrease. He emphasised that oil price decrease does not necessarily stimulate economic growth. Mork et al. (1994) found an asymmetric effect of oil price in most OECD countries. Hooker (1996a) argued that the linear effect of oil price on economic growth is weaker for data that was recorded after 1973. Therefore, he argued that studies with data after 1973 need to emphasise the role of asymmetric effect. Narayan and Narayan (2007) examined the volatility of oil price and found evidence of asymmetry. In more recent studies on SSA countries, Gbatu et al. (2017a) found that heavy dependence on oil was a major cause of asymmetry in a panel of Economic Community of West African States (ECOWAS). Another study by Gbatu et al. (2017b) and Aliyu (2011) also found asymmetric effects of oil price in Liberia and Nigeria respectively. However, most studies on developing countries and SSA countries are few and inconclusive and mostly comprise single-country analysis. These studies include Ayadi (2005) on Nigeria, Balcilar et al. (2017) on South Africa and Semboja (1994) on Kenya. This paper employs a panel study analysis on oil-importing SSA countries, and will further improve the literature on oil price and economic growth in the region by employing a dynamic panel-ARDL method. Most panel studies that exist have been done for the Organisation of Petroleum Exporting Countries (OPEC), the MENA region, and developed countries.

This study tests whether economic growth responds asymmetrically to changes in real oil prices. While there have been various studies on the subject, particularly with time-series data, this paper happens to be one of the pioneer studies to extend the discussions on asymmetry in the real oil price and economic growth nexus using panel data. This study is novel in various aspects. First, the choice of methodology, the panel-ARDL, means

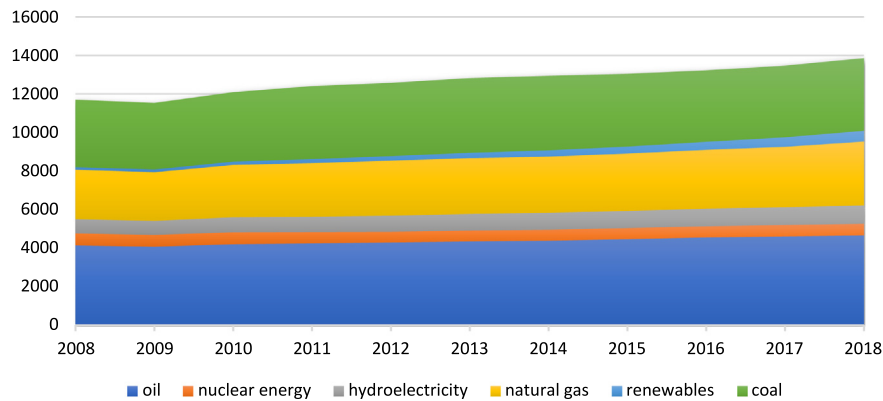
robust inferences are made from panel data analysis because of its large dataset characteristics. It also allows the addition of control variables in the model. Furthermore, the panel-ARDL analysis accommodates country-specific effects and gains degrees of freedom by analysing a panel of countries, which may not be possible in time series analysis, thereby improving the consistency of the estimation. The panel-ARDL also allows the intercept, short-run coefficients and cointegrating terms to differ across cross-sections (Perasan et al. 1999). Second, the asymmetric effect of the oil price, especially in panel studies, is to the best of our knowledge quite scant. Most studies on asymmetric effects of oil price have been time series (Balke et al., 2010; Lardic and Mignon, 2008; Raheem, 2017). Third, most of these studies have concentrated on oil prices and the exchange rates in developed countries, with little emphasis on other macroeconomic variables, such as economic growth, oil consumption and investment for SSA countries (Benedictow et al. 2013); (Narayan et al., 2008; Huang and Guo, 2007); (Camarero and Tamarit 2002); (Fowowe, 2014; Iwayemi and Fowowe, 2011). With recent developments in the oil price dynamics, this paper fills the knowledge gap of oil price fluctuations by conducting research on oil-importing SSA countries.

In this study, selected low-income and oil-importing countries in SSA are investigated for the period 1990 to 2018 to establish the impact of oil price on economic growth. The rest of the paper is organised as follows: Section 2 reviews a summary of the literature. Section 3 presents the dataset and common sample of variables in the study, and Section 4 presents and analyses the results. Section 5 discusses the findings and concludes and offers policy recommendations.

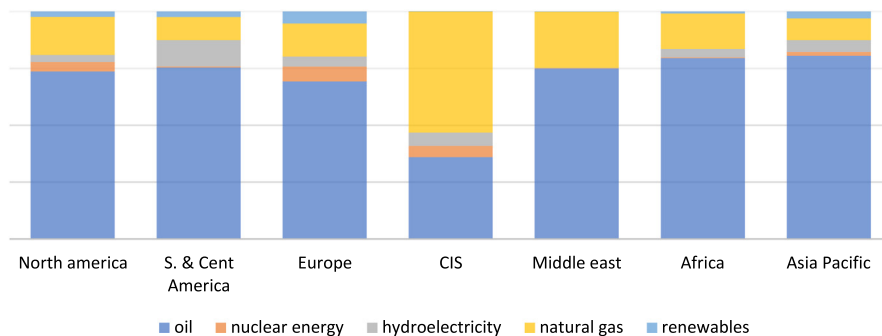
## 2. Literature review

In this section, we examine the scholarly literature on the oil price-growth nexus to give clear direction to the aim and understanding of the contribution of this study. Existing literature emphasised that lower oil price boosts economic growth. However, the oil price plunge of 1986 failed to support stronger growth and economic boom due to uncertainty in global demand, factor reallocation and structural changes. Therefore, the literature became more intrigued by the asymmetric effect of oil price changes on economic growth (Kilian, 2014; Jiménez-Rodríguez and Sánchez, 2005).

This paper reviews previous country-specific and cross-country studies. A number of country-specific studies have examined the oil price-growth relationship in the context of single-country analysis. Earlier studies including Hamilton (1983, 1996) found an inverse relationship between oil price increase and aggregate economic activities. Similarly, Mork and Hall (1980) using a simulated model found that a significant change in the price of oil has a significant adverse effect on the US economy. Guo and Kliesen (2005) also analysed the impact of oil price on the US economy and found a negative impact of oil prices on output and other macroeconomic variables. Rafiq et al. (2009) examined the nexus between oil prices on output and other macroeconomic variables for the Thailand economy. They also confirmed a negative impact of oil prices on output and other macroeconomic variables. Similarly, Du and Wei (2010) examined the effect of oil price on economic growth in China using the VAR methodology. The study employed the linear and non-linear specification of oil price. For the linear specification, the authors found that a 100% increase in oil price had a positive effect on economic growth, and caused an increase in GDP by 9%. The inflation rate also rose by 2.08%. The non-linear model specification, however, showed different results. They found that a 100% increase in oil prices had a negative effect on Chinese GDP growth. GDP decreased by 17%



**Fig. 1.** World consumption by energy sources (million tonnes of oil equivalent).  
Source: Authors' computation from BP Statistical Report, 2019.



**Fig. 2.** Regional consumption by energy sources in 2018.  
Source: Authors' computation from BP Statistical Report, 2019.

when employing the [Mork \(1989\)](#) asymmetry transformation, a 10% decrease for [Hamilton \(1996\)](#) transformation and a 1% decrease for [Lee et al. \(1995\)](#) transformation. The study confirmed a non-linear and asymmetric relationship between oil prices and economic growth as discussed in the theoretical literature.

[Gbatu et al. \(2017b\)](#) focused on a low-income country and examined the impact of oil price shocks on Liberia using the ARDL Bounds test. They found an asymmetric relationship between oil price and growth. Moreover, the impact of oil price was found to be limited to the short run. They also found that there was no positive impact on GDP growth in the short run during periods of decreasing oil prices. Unlike traditional studies, falling oil prices do not translate into more production inputs in developing countries. Rather, it increases savings and opportunity for corruption. However, the increase in oil prices stimulated the Liberian economy during the period examined. Similarly, [Tefera et al. \(2012\)](#) focused on another low-income country by examining the implication of oil price shocks and oil subsidy on the Ethiopian economy. They found that the increase in oil price depreciates the Ethiopian Birr and ultimately negatively affects economic growth. In another study on Ethiopia, [Fekadu \(2005\)](#) examined the impact of oil price increases on the Ethiopian economy. He found that an increase in the price of oil has an effect on core inflation and growth but minimal effect on the headline inflation.

Regarding cross-country studies, [Cunado and Perez-de Gracia \(2003\)](#) analysed 14 European countries using quarterly data from 1960 to 1999 and applying a VAR technique. They found a direct relationship between oil price and GDP for half of the countries, but no direct relationship for the other half. They explained that choosing either world oil prices or a national real oil price index influences the difference between oil prices and outputs. They

also found that only the United Kingdom and Ireland exert long-run relationships between oil prices and outputs. Therefore, the effect of oil price shocks on economic growth is restricted to the short-run. Similarly, [Rafiq and Salim \(2011\)](#) examined the impact of oil price volatility on six Asian emerging countries including China, Indonesia, Philippines, India, Malaysia and Thailand. The authors employed the VAR analysis for each country. Results for China and Malaysia showed that oil price volatility impacts output growth in the short run. Philippines' result showed that oil price impacts only inflation while oil price volatility impacts both GDP growth and inflation in India and Indonesia. For Indonesia however, the impact was before and after the Asian crisis. For Thailand, oil price volatility impacts GDP growth but seems to disappear after the Asian crisis. [Jiménez-Rodríguez and Sánchez \(2005\)](#), in an empirical analysis of some OECD countries, further explained that oil price impacts are non-linear on real GDP. Oil price increases have a larger impact than oil price decreases. In fact, oil price decreases are found to be statistically insignificant in most cases. For oil-importing countries, oil price shocks have a negative impact on economic activities for all countries (USA, Euro Area, Canada, France, Italy and Germany) except Japan. For the oil-exporting countries, the UK was negatively impacted by oil price shocks while Norway gained from the oil price shocks during the period examined.

Similarly, [Berument, Ceylan and Dogan \(2010\)](#) examined the impact of oil price shocks on economic growth in the MENA region during the period 1960 to 2003 using the dynamic vector autoregressive (DVAR) model. The results show a positive impact on Iran, Iraq, Algeria, Jordan, Kuwait, Oman, Syria, Tunisia and the United Arab Emirates, while Bahrain, Djibouti, Egypt, Morocco and Yemen show no significant statistical relationship. [Gbatu et al. \(2017a\)](#) examined the asymmetric effects of oil price shocks



and exchange rate fluctuations on real GDP for a panel of ECOWAS countries. The fixed-effects model was employed. The sample was divided into three groups: all the ECOWAS countries, the net oil-exporting countries and the net oil-importing countries. The results showed a linear and asymmetric impact of oil prices on real GDP for the whole sample of ECOWAS countries and the net oil-importing countries. Moreover, exchange rate volatility negatively impacts the sample for the whole of ECOWAS and net oil-importing countries samples. [Bacon \(2005\)](#) examined the impact of higher crude oil prices for 131 countries. The study found that the impact was more severe for poorer oil-importing countries compared to developed countries. Therefore, a 10% increase in the price of crude oil caused a 4% decrease in the economic growth of countries with GDP per capita below US\$300. If the increase in the price of oil is doubled, then the shock was also doubled. However, countries with GDP per capita of over US\$9,000 and higher foreign reserves, experienced an average of 0.4% decrease in their economic growth. [Salisu and Isah \(2017\)](#) examined the non-linear relationship between oil price and stock price in oil-importing and oil-exporting countries. They found that stock prices respond asymmetrically to changes in oil prices in both country groups.

Based on this review of previous studies, it is evident that the literature has identified oil price as a dominant commodity and determinant of economic growth. However, most of the studies have used the linear specification of the oil price variable, which might not be adequate. Studies such as [Du and Wei \(2010\)](#), [Gbatu et al. \(2017a,b\)](#), [Jiménez-Rodríguez and Sánchez \(2005\)](#) and [Raheem \(2017\)](#) identified the importance of including non-linear model specification of the oil price. Our study, therefore, takes a cue from these latter studies by specifying oil price both in its linear and non-linear forms. Using the non-linear form of the oil price in a panel data, we differentiate this present study from other studies and ascertain if our result differs from other panel studies in relation to oil price-growth nexus. Also, the shortage of panel studies on low-income countries regarding the critical role of oil price on their economies necessitates this present study.

### 3. Data, model and methodology

#### 3.1. Data

This study examines and analyses the impact of real oil price on economic growth from 1990 to 2018 for a panel dataset of seven low-income and net oil-importing countries in SSA. This study used the [World Bank \(2018a,b\)](#) classification of economies. The countries include Ethiopia, Gambia, Mali, Mozambique, Senegal, Tanzania and Uganda. The sample period is favoured because they form a group of low-income countries in SSA with high consumption of oil. Annual data was employed in this study and sourced from World Development Indicator (WDI), US Energy Information Administration (EIA) and BP Statistical Report, 2019. Brent crude oil price is used in this study because it is a major benchmark in the global international market. Due to the unavailability of data for domestic oil price for the countries, the Brent crude oil price best represents oil price as a uniform substitute (see [Gbatu et al., 2017b](#); [Behmiri and Manso, 2013](#)). The Brent oil price is adjusted for inflation, using the consumer price index of each country, to obtain the real oil price. Real GDP per capita, gross fixed capital formation, labour force, inflation and trade openness are sourced from the World Development Index (WDI, 2019), while oil price and oil consumption data are sourced from British Petroleum (BP Statistical Review, 2019) and the US Energy Information Administration (EIA), 2019 respectively. The real exchange rate is sourced from the Bruegel database ([Darvas, 2012](#)). [Table 1](#) presents the common descriptive statistics of the sample. There is significant variation in the minimum and maximum values of oil price, with a minimum value of the real oil price is 0.160 and maximum of 4.945.

**Table 1**

Summary of common descriptive statistics.

	Mean	Median	Maximum	Minimum	Std. Dev.
LNRGDPC	6.241	6.230	7.344	5.102	0.528
ROP	0.639	0.521	4.945	0.160	0.489
OC	20.795	16.400	74.000	1.318	17.411
GFC	22.500	21.319	43.051	4.562	8.026
LNLF	15.631	15.839	17.779	12.598	1.307
REER	111.011	101.674	213.519	71.846	25.664
INF	8.419	5.700	63.100	−8.484	10.672
TOP	54.767	52.396	131.485	23.981	17.624

Note: Std. Dev. represents standard deviation, LNRGDP is the log of real GDP per capita, ROP is the real Brent oil price, OC is oil consumption, GFC is gross fixed capital formation, LNLF is the log of the labour force, REER is the real exchange rate, and TOP is trade openness.

#### 3.2. Model

Oil is a normal good. Its price and income determine the amount to be consumed. Oil price and oil consumption also have an impact on the production capacity of a country. This study empirically examines that economic growth is a function of real oil price and other control variables. The model modifies [Behmiri and Manso \(2013\)](#) who examined the oil consumption, oil price and economic growth nexus, and [Lescaroux and Mignon \(2008\)](#) who examined the effect of oil price on growth. Our model, therefore, examines the impact of oil price on economic growth, conditioned on some control variables (oil consumption, gross fixed capital formation, labour force, real exchange rate, inflation and trade openness).

Real GDP per capita =  $f$  (real oil price, oil consumption, gross fixed capital formation, labour force, real exchange rate, inflation, trade openness)

The functional panel form is further expressed in the form of an equation given as:

$$RGDPC_{it} = \alpha_i + \vartheta_{it} + \beta_{1i}ROP_{it} + \beta_{2i}OC_{it} + \beta_{3i}GFC_{it} + \beta_{4i}LF_{it} + \beta_{5i}REER_{it} + \beta_{6i}INF_{it} + \beta_{7i}TOP_{it} + \mu_i \quad (1)$$

where RGDPC represents real GDP per capita, ROP depicts real oil price, OC is oil consumption, GFC is gross fixed capital formation, LF depicts labour force, REER represents real exchange rate, INF is inflation and TOP is trade openness.

#### 3.3. Methodology

Oil price has an effect on microeconomic and macroeconomic variables over a period of time in future periods. Therefore, the panel-ARDL model introduced by Pesaran and Smith (1995) and Pesaran and Shin (1997) was employed to analyse both the short-run and long-run relationships. This study favours PMG estimator, which is considered consistent and efficient. The statistical significance of the long-run coefficient, the size of the group-specific error adjustment coefficients and the short-run coefficients are observed.

Following Pesaran et al. (1999), the panel-ARDL (p,q,...q) dynamic specification model is specified below as:

$$y_{it} = \sum_{j=1}^p \lambda_{ij}y_{i,t-j} + \sum_{j=0}^q \sigma_{ij}X_{i,t-j} + \mu_i + \varepsilon_{it} \quad (2)$$

where  $y_{it}$  is the dependent variable for group  $i$  and  $X_{i,t-j}$  is a  $k \times 1$  vector explanatory variables for group  $i$ ,  $\sigma_{ij}$  are the  $k \times 1$  vector of coefficients, the groups are denoted as  $i = 1, 2, \dots, N$  time periods as  $t = 1, 2, \dots, T$  and  $\mu_i$  are the fixed effects.

**Table 2**  
Panel unit root.

Variable	Method	At level		At first difference	
		Intercept	Trend	Intercept	Trend
LNRGDPC	Levin, Lin & Chu t*	0.43(0.665)	−2.00**(0.023)	−4.49*** (0.000)	−3.95*** (0.000)
	Breitung t-stat	−	1.36(0.913)	−	−2.03*** (0.021)
	IPS W-stat	3.44(1.000)	−0.86(0.194)	−5.90*** (0.000)	−4.61*** (0.000)
	ADF-Fisher Chi-square	4.36(0.993)	22.30*(0.073)	62.23*** (0.000)	48.96*** (0.000)
	PP-Fisher Chi-square	5.14(0.984)	27.70** (0.016)	105.32*** (0.000)	94.26*** (0.000)
ROP	Levin, Lin & Chu t*	0.73(0.767)	2.20(0.986)	−7.05*** (0.000)	−5.29*** (0.000)
	Breitung t-stat	−	−2.50*** (0.006)	−	−
	IPS W-stat	−2.12** (0.017)	−0.72(0.236)	−	−5.19*** (0.000)
	ADF-Fisher Chi-square	27.51** (0.017)	18.09(0.203)	−	50.76*** (0.000)
	PP-Fisher Chi-square	55.42*** (0.000)	125.35*** (0.000)	−	−
OC	Levin, Lin & Chu t*	2.76(0.997)	−0.37(0.354)	−5.25*** (0.000)	−5.46*** (0.000)
	Breitung t-stat	−	2.93(0.998)	−	−1.03(0.153)
	IPS W-stat	5.42(1.000)	0.91(0.819)	−5.28*** (0.000)	−5.41*** (0.000)
	ADF-Fisher Chi-square	1.70(1.000)	11.81(0.622)	58.10*** (0.000)	53.63*** (0.000)
	PP-Fisher Chi-square	1.39(1.000)	9.97(0.764)	105.41*** (0.000)	330.82*** (0.000)
REER	Levin, Lin & Chu t*	−1.26(0.104)	−1.05(0.147)	−7.54*** (0.000)	−7.76*** (0.000)
	Breitung t-stat	−	−1.70** (0.044)	−	−5.67*** (0.000)
	IPS W-stat	−1.87** (0.031)	−0.54(0.295)	−8.30*** (0.000)	−8.72*** (0.000)
	ADF-Fisher Chi-square	22.74* (0.065)	13.69(0.473)	89.38*** (0.000)	89.56*** (0.000)
	PP-Fisher Chi-square	25.02** (0.034)	12.38(0.575)	126.60*** (0.000)	276.07*** (0.000)
GFC	Levin, Lin & Chu t*	−0.39(0.347)	1.31(0.905)	−2.45*** (0.007)	−0.45(0.327)
	Breitung t-stat	−	−1.25(0.106)	−	−4.54*** (0.000)
	IPS W-stat	−0.66(0.254)	0.07(0.528)	−6.71*** (0.000)	−5.00*** (0.000)
	ADF-Fisher Chi-square	14.58(0.407)	11.21(0.669)	69.59*** (0.000)	48.83*** (0.000)
	PP-Fisher Chi-square	25.06** (0.034)	22.39* (0.071)	159.25*** (0.000)	142.54*** (0.000)
LNLf	Levin, Lin & Chu t*	2.67(0.996)	−0.88(0.191)	0.13(0.553)	1.05(0.853)
	Breitung t-stat	−	−4.99*** (0.000)	−	−
	IPS W-stat	6.27(1.000)	−0.99(0.161)	−1.36* (0.087)	−0.23(0.410)
	ADF-Fisher Chi-square	0.62(1.000)	26.88*** (0.020)	25.23** (0.032)	−
	PP-Fisher Chi-square	11.50(0.647)	16.91(0.261)	28.71** (0.011)	18.54(0.183)
INF	Levin, Lin & Chu t*	−3.32*** (0.000)	−3.28*** (0.000)	−	−
	Breitung t-stat	−	−3.41*** (0.000)	−	−
	IPS W-stat	−3.94*** (0.000)	−2.88*** (0.002)	−	−
	ADF-Fisher Chi-square	42.11*** (0.000)	32.48*** (0.003)	−	−
	PP-Fisher Chi-square	56.02*** (0.000)	59.18*** (0.000)	−	−
TOP	Levin, Lin & Chu t*	0.49(0.688)	0.52(0.700)	−3.86*** (0.000)	−2.22** (0.013)
	Breitung t-stat	−	−0.09(0.464)	−	−5.72*** (0.000)
	IPS W-stat	0.22(0.585)	0.12(0.550)	−7.59*** (0.000)	−6.48*** (0.000)
	ADF-Fisher Chi-square	15.20(0.365)	14.80(0.392)	80.62*** (0.000)	64.48*** (0.000)
	PP-Fisher Chi-square	33.53*** (0.002)	36.66*** (0.001)	−	−

The re-parameterised panel-ARDL model of equation (...) is specified to structure the long-run and short-run dynamic panel model:

$$\Delta y_{it} = (\phi_i y_{i,t-1} + \gamma_i' X_{i,t}) + \sum_{j=1}^{p-1} \lambda_{ij}^* y_{i,t-j} + \sum_{j=0}^{q-1} \sigma_{ij}^* X_{i,t-j} + \mu_i + \varepsilon_{it} \quad (3)$$

where  $\Delta y_{it} = y_{it} - y_{i,t-1}$ ,  $\phi_i$  is the speed of adjustment. If  $\phi_i = 0$ , this indicates that the variables do not have a long-run relationship. The  $\phi_i$  is expected to be negative and statistically significant since it is assumed that the variables converge to long-run equilibrium in case of any disturbance. Equation  $(\phi_i y_{i,t-1} + \gamma_i' X_{i,t})$  is the error correction term that represents the long-run model. Equation  $(\sum_{j=1}^{p-1} \lambda_{ij}^* y_{i,t-j} + \sum_{j=0}^{q-1} \sigma_{ij}^* X_{i,t-j} + \mu_i)$  represents the short-run model.

Therefore, the panel-ARDL model of the relationship between real oil price and economic growth is:

$$\begin{aligned} \Delta RGDPC_{it} = & \phi_i (RGDPC_{i,t-1} + ROP_{i,t-1} + \gamma_i' X_{i,t}) \\ & + \sum_{j=1}^{p-1} \lambda_{ij}^* RGDPC_{i,t-j} + \sum_{j=1}^{p-1} \delta_{ij}^* OP_{i,t-j} \\ & + \sum_{j=0}^{q-1} \sigma_{ij}^* X_{i,t-j} + \mu_i + \varepsilon_{it} \end{aligned} \quad (4)$$

where  $RGDPC_{it}$  is real GDP per capita,  $ROP_{it}$  is the real oil price,  $\alpha$  is a vector of constants,  $X_{i,t}$  is the vector of explanatory variables of real oil price, oil consumption, gross fixed capital formation, labour force, real exchange rate and trade openness,  $\mu_{it}$  is the white noise error term;  $\Delta$  is the difference operator, and  $n$  is the lag length. Eq. (5) outlines the dependent and independent variables in a model form.

$$\begin{aligned} \Delta RGDPC_{it} = & \alpha_{1j} + \sum_{k=1}^n \partial_{11ik} \Delta RGDPC_{it-k} + \sum_{k=1}^n \partial_{12ik} \Delta ROP_{it-k} \\ & + \sum_{k=1}^n \partial_{13ik} \Delta OC_{it-k} + \sum_{k=1}^n \partial_{14ik} \Delta GFC_{it-k} \\ & + \sum_{k=1}^n \partial_{15ik} \Delta \ln LF_{it-k} + \sum_{k=1}^n \partial_{16ik} \Delta REER_{it-k} \\ & + \sum_{k=1}^n \partial_{17ik} \Delta TOP_{it-k} + \varphi_{1i} ECT_{1it-1} + \mu_{1it} \end{aligned} \quad (5)$$

The general model is estimated for the panel of seven countries. This study favours the panel-ARDL for four reasons (Pesaran and Shin 1999; Asongu et al., 2016). First, the panel-ARDL can be applied whether the variables are integrated of order I(0) or I(1). Second, estimations from the panel-ARDL technique are unbiased in showing the long-run relationship among variables.

The t-statistics estimates are also valid even in the presence of endogenous explanatory variables. Third, the panel-ARDL, unlike other methods, employs a single reduced form equation instead of a system of equations in other approaches (Pesaran and Shin 1999). Fourth, the panel-ARDL is suitable for any sample size. Other cointegration tests are sensitive to sample size and cannot be employed with small sample size. The panel-ARDL has also gained widespread usage in recent years to analyse relationships among economic variables (Asongu et al., 2016).

This study also employed the recently developed NARDL model by Shin et al. (2014). Although the model was developed for time series, we decomposed the real oil price into increase and decrease for all countries and adopted it for all cross-sections. The advantage of this model is that it examined both the long-run and short-run asymmetric effects of real oil price on growth. The NARDL decomposes oil price into negative and positive changes. The real oil price was decomposed because it is believed that economic agents respond in various manners to oil price changes (Raheem, 2017).

$$\begin{aligned} \Delta RGDP_{it} = & \phi_i (RGDP_{i,t-1} + ROP_{i,t-1}^+ + ROP_{i,t-1}^- + \gamma_i' X_{i,t}) \\ & + \sum_{j=1}^{p-1} \lambda_{ij}^* RGDP_{i,t-j} + \sum_{j=1}^{q-1} \delta_{ij}^* ROP_{i,t-j}^+ \\ & + \sum_{j=1}^{p-1} \varphi_{ij}^* ROP_{i,t-j}^- + \sum_{j=0}^{q-1} \sigma_{ij}^* X_{i,t-j} + \mu_i + \varepsilon_{it} \end{aligned} \quad (6)$$

The real oil price is decomposed in Eq. (6).  $ROP^+$  and  $ROP^-$  represent the real oil price positive and real oil price negative. Other variables remain as earlier defined.

The theoretical definition of the decomposed real oil prices are:

$$ROP_{i,t}^+ = \sum_{j=1}^t \Delta ROP_{i,j}^+ = \sum_{j=1}^t \max(\Delta ROP_{i,j}^+, 0) \quad (7)$$

$$ROP_{i,t}^- = \sum_{j=1}^t \Delta ROP_{i,j}^- = \sum_{j=1}^t \min(\Delta ROP_{i,j}^-, 0) \quad (8)$$

## 4. Empirical results

### 4.1. Panel unit root tests

In order to establish the variables' order of integration in a panel framework, this study employs panel unit root tests. The unit root tests consist of Levin et al. (2002) and Breitung (2000) t-statistics that assume a homogeneous or common unit root process. Also included are Im et al. (2003) W-statistic, ADF-Fisher and PP-Fisher Chi-square statistics that assume a heterogeneous or individual unit root process (Maddala and Wu, 1999; Choi, 2001). Table 2 presents the results from the panel unit root tests. The results show that all the variables are stationary at the first difference for all the five-panel unit root tests except inflation which is stationary at level.

### 4.2. Panel cointegration tests

The panel cointegration tests are conducted to determine if there is a cointegrating relationship between the variables of interest. Panel cointegration tests proposed in the literature include Pedroni (1999, 2004), Kao (1999) and Fisher (1932) combined tests. This study employs three cointegration tests. Both Kao and Fisher tests reject the null hypothesis of no cointegration at 1% significant level (see Tables 3 and 4).

**Table 3**

Kao panel cointegration test.

	Statistic	Prob.
ADF	−3.300***	0.001

Note: \*\*\*, \*\* and \* imply significance levels at the 1, 5, and 10% levels, respectively.

**Table 4**

Johansen Fisher panel cointegration test.

Hypothesised No. of CE(s)	Trace test		Max-eigen statistics	
	Statistics	Prob.	Statistics	Prob.
None	798.0***	0.0000	277.4***	0.0000
At most 1	344.8***	0.0000	206.3***	0.0000
At most 2	231.0***	0.0000	112.8***	0.0000

Note: \*\*\*, \*\* and \* imply significance levels at the 1%, 5%, and 10% levels, respectively.

**Table 5**

Results of Pedroni's (2004) cointegration test.

	Statistic	Prob.	Weighted statistic	Prob.
Within-dimension				
Panel v-Statistic	0.343	0.366	−0.523	0.700
Panel rho-Statistic	1.529	0.937	1.931	0.973
Panel PP-Statistic	−2.234***	0.004	−0.709	0.239
Panel ADF-Statistic	−1.990**	0.023	−1.754**	0.040
Between-dimension				
Group rho-Statistic	3.020		0.999	
Group PP-Statistic	−0.155		0.439	
Group ADF-Statistic	−2.197**		0.014	

Note: \*\*\*, \*\* and \* imply significance levels at the 1%, 5%, and 10% levels, respectively.

The Pedroni cointegration test is presented in Table 5. Pedroni (1999, 2004) posits a residual-based cointegration test for dynamic panels in which the short-run and the long-run coefficients are allowed to differ across cross-sections. The Pedroni cointegration test employs seven statistics as reported in Table 5.

From Table 5, the Pedroni cointegration test shows that for LIC, only three – panel PP, panel ADF and group ADF – out of the seven statistics are significant in rejecting the null hypothesis of no cointegration. However, these three tests are among the four tests that Karaman-Örsal (2007) considered to have the best performance. Also, among the three statistics that are significant in this study, panel ADF and group ADF are regarded as more reliable statistics (Pedroni, 2004; Asongu et al., 2016). Therefore, from our results, the panel PP reject the null hypothesis of no cointegration at 1% while the panel ADF and group ADF statistics reject the null hypothesis at 5% level of significance.

### 4.3. Model estimation

After confirming the stationarity of the panel series and the long-run cointegration relationship, the next step is to conduct the long-run and short-run estimates using the panel-ARDL. As discussed in the methodology section, the panel-ARDL is the most appropriate for this study. The Hausman test, however, needs to be conducted in order to make a selection between PMG and MG. The PMG estimator assumes that the long-run coefficients are equal across all cross-section, while the MG estimator assumes heterogeneous long-run coefficients. The Hausman test is therefore conducted in order to make a selection between MG and PMG. A homogeneous estimator favours the PMG as the more efficient estimator while a heterogeneous estimator favours MG as the more efficient estimator (Blackburne and Frank 2007). The results of the Hausman test are presented in Table 6.

**Table 6**

Hausman test for long-run homogeneity (Linear model).

Regressor	MG	PMG
ROP	−0.173	0.931
OC	−0.006	−0.004
GFC	0.0055	−0.045
LNLF	1.287	3.696
REER	0.002	0.006
INF	−0.007	0.016
TOP	−0.007	0.017
Hausman	5.54(0.595)	

Note: *t*-statistics are in parenthesis. For all probability values, \*, \*\* and \*\*\* denote significance at 10%, 5% and 1% level of significance, respectively.

According to the results of the Hausman test, the test statistic is 5.54 with a probability value of 0.595. Therefore, the null hypothesis cannot be rejected. As a result, the PMG is the preferred estimator since it is an efficient estimator under the null.

Table 7 presents the PMG estimation of the relationship between real oil price and economic growth with respect to other control variables. As illustrated in Table 7, panel I present the long-run pooled estimates while panel II presents the short-run and country-specific estimates from 1990 to 2018.

The PMG long-run estimates show that real oil price has a negative and significant impact on real GDP per capita at 1% critical value. The result meets the apriori expectation that oil price increase would have a negative effect on economic growth for oil-importing countries. The control variables also show a significant impact on real GDP except for gross fixed capital formation. For the short-run estimates, the real oil price does not seem to have a significant effect on growth. However, the error correction term that shows the speed of adjustment to steady-state fulfils the theoretical requirement and is negative and significant. The country-level short-run estimates are presented in Table 8.

Table 8 shows the short-run panel for the countries in the study. The real oil price has a negative effect on real GDP per capita in five countries in the panel (Gambia, Mali, Mozambique, Senegal and Uganda). The rest of the countries showed a positive effect of oil price on growth. Apriori expectation is that oil price increases would have a negative effect on economic growth for oil-importing countries. This implies that the negative effect of oil price on economic growth is not immediate for all countries

since the short-run estimate shows mixed effects. However, the pooled long-run estimates show a negative effect of the real oil price on growth. A possible explanation for the result could be explained by the energy sources of low-income countries in SSA. Low-income countries in SSA depend on biofuels for their energy needs and the demand for oil has only recently grown in the region (see (Suleiman, 2013; Gbatu et al., 2017b)). Another explanation may be that oil prices have been argued in the literature to not have a serious negative effect on economic growth for data that spans beyond the 1980s (Hooker, 1996a,b). Moreover, the effect of oil price on economic growth can change over time because the volume of oil that low-income countries import and consume might be insignificant. These economies might be growing due to economies of scale from labour intensiveness in the short run.

Regarding the speed of adjustment, the coefficients of the individual countries' error correction terms (ECT) are within the 0 and 1 range and negative for five of the countries in the panel. All the ECTs are also statically significant.

#### 4.4. Asymmetric effect of oil price

As mentioned earlier, the asymmetric effect decomposes the real oil price into decrease and increase in real oil price. Table 9 presents the Hausman test while Table 10 presents the results for the non-linear relationship between the real oil price and economic growth.

The test statistic results of the Hausman test is 5.77 with a probability value of 0.673. Therefore, the null hypothesis cannot be rejected and the PMG becomes the preferred estimator since it is an efficient estimator under the null.

By decomposing the real oil price into oil price increase and decrease, the asymmetric effect becomes obvious. The PMG estimates for the long run depict that real oil price positive (increase) have a significant negative impact on real GDP per capita, while real oil price negative (decrease) has a positive significant impact on real GDP per capita. More so, both real oil price negative and real oil price positive are not significant in the short run. Therefore, the asymmetric effect of oil price is delayed and limited to the long run. Changes in oil prices have significant macroeconomic, financial and policy implications. A sustained decline in oil price, therefore, will augment growth and boost the external

**Table 7**

Pooled mean group estimates.

Panel I: Estimated long run coefficients (Dependent variable: LNREGDPC (log of real GDP per capita))				
Regressor	PMG	Std. Error	<i>t</i> -stat	Prob
ROP	−0.931***	0.032	−3.486	0.001
OC	0.004***	0.001	3.680	0.000
GFC	0.045	0.002	1.332	0.185
LNLF	3.696***	0.082	9.722	0.000
REER	−0.006***	0.001	−2.808	0.006
INF	−0.016***	0.001	−3.698	0.000
TOP	0.017**	0.001	2.300	0.023
Panel II: Estimated short-run coefficients (Dependent variable: LNREGDPC)				
ECT	−0.136**	0.062	−2.209	0.029
D(LNREGDPC(−1))	0.012	0.107	0.107	0.915
D(ROP)	0.016	0.026	0.600	0.550
D(OC)	−0.002	0.003	−0.619	0.537
D(GFC)	0.001	0.001	0.648	0.518
D(LNLF)	−0.044	1.971	−0.022	0.982
D(REER)	0.000	0.000	0.702	0.484
D(INF)	0.001	0.000	1.442	0.152
D(TOP)	0.000	0.001	0.461	0.646
C	−0.813**	0.418	−1.945	0.054
Akaike info criterion	−4.221			
Schwarz criterion	−2.965			
S.E. of regression	0.026			

Note: For all probability values, \*, \*\* and \*\*\* denote significance at 10%, 5% and 1% level of significance, respectively.



**Table 8**  
Country-level short-run PMG estimates.

	Ethiopia	The Gambia	Mali	Mozambique	Senegal	Tanzania	Uganda
COINTEQ01	0.1110***	0.0201***	−0.2281***	−0.3359***	−0.1912***	−0.2656***	−0.0622***
D(LNRGDP(−1))	0.4527***	−0.2169***	−0.2478***	−0.2836***	−0.0286	0.2620***	0.1428**
D(ROP)	0.1686***	−0.0342***	−0.0163***	−0.0036**	−0.0023***	0.0088***	−0.0118***
D(OC)	0.0039***	−0.0059**	−0.0168***	−0.0002***	0.0028***	−0.0004***	0.0043***
D(GFC)	0.0076***	0.0017***	−0.0001***	−0.0022***	−0.0039***	0.0003***	0.0030***
D(LNLF)	−5.4647	9.6071***	2.7758	−5.4277**	0.7612**	−1.4676***	−1.0898
D(REER)	−0.0019***	0.0011***	0.0005***	0.0014***	0.0006***	−0.0003***	0.0007***
D(INF)	−0.0008***	0.0022***	0.0015***	0.0009***	−0.0001***	−0.0001***	0.0004***
D(TOP)	0.0009***	−0.0015***	−0.0010***	−0.0004***	0.0011***	−0.0001***	0.0028***
C	1.1261**	−0.2260***	−1.3747***	−2.1461**	−0.9469***	−1.7677***	−0.3559

For all probability values, \*, \*\* and \*\*\* denote significance at 10%, 5% and 1% level of significance, respectively.

**Table 9**  
Hausman test for long-run homogeneity (Nonlinear model).

Regressor	MG	PMG
ROP_POS	−1.495	−1.217
ROP_NEG	−0.803	0.411
OC	−0.023	0.005
GFC	−0.032	−0.049
LNLF	2.870	5.048
REER	0.015	0.004
INF	−0.020	−0.015
TOP	0.036	0.017
Hausman	5.77(0.673)	

Note: *t*-statistics are in parenthesis. For all probability values, \*, \*\* and \*\*\* denote significance at 10%, 5% and 1% level of significance, respectively. ROP\_POS represents an increase in oil price, while ROP\_NEG depicts a decrease in oil price. All other variables remain as previously defined.

**Table 10**  
Asymmetry pooled mean group estimates.

Panel I: Estimated long run coefficients (Dependent variable: LNRGDPC)				
Regressor	PMG	Std. Error	<i>t</i> -stat	Prob
ROP_POS	−1.217**	0.040	0.457	0.049
ROP_NEG	0.411***	0.030	−5.042	0.000
OC	0.005***	0.001	2.707	0.008
LNLF	5.048***	0.127	3.026	0.003
GFC	0.049*	0.001	1.924	0.057
REER	−0.004***	0.000	−2.738	0.007
INF	−0.015***	0.001	−4.657	0.000
TOP	0.017***	0.001	3.184	0.002
Panel II: Estimated short-run coefficients (Dependent variable: LNRGDPC)				
ECT	−0.151**	0.068	−2.212	0.029
D(LNRGDP(−1))	0.026	0.109	0.237	0.813
D(ROP_POS)	0.043	0.042	1.021	0.309
D(ROP_NEG)	−0.001	0.013	−0.079	0.937
D(OC)	−0.003	0.003	−0.886	0.378
D(LNLF)	0.268	2.001	0.134	0.894
D(GFC)	0.006	0.001	0.307	0.760
D(REER)	0.004	0.000	0.796	0.428
D(INF)	0.001**	0.000	1.908	0.059
D(TOP)	0.000	0.001	0.162	0.872
C	0.014	0.089	0.153	0.879
Akaike info criterion	−4.194			
Schwarz criterion	−2.807			
S.E. of regression	0.027			

For all probability values, \*, \*\* and \*\*\* denote significance at 10%, 5% and 1% level of significance, respectively. ROP\_POS represents an increase in real oil price while ROP\_NEG depicts a decrease in real oil price. All other variables remain as previously defined.

and fiscal balance of oil-importing countries. Declining oil prices also provide considerable opportunity to increase savings and reform fuel subsidies, which are substantial in most developing countries.

**Table 11**  
Cross-sectional dependence test for panel data.

Test	Statistic	Prob	
Breusch–Pagan Chi-square	19.499	0.553	
Pearson LM Normal	−1.312	0.190	
Pearson CD Normal	1.107	0.268	
Friedman Chi-square	39.248	0.077	
Frees Q	−0.023	1%	0.166
		5%	0.116
		10%	0.089

#### 4.5. Diagnostics tests

To establish the consistency and validity of the selected model, we conducted diagnostic tests. We begin with a cross-sectional dependence test. Baltagi (2005) reports that cross-sectional dependence may exist and be problematic in panel data. Table 11 depicts the result of the cross-sectional dependence tests and shows that the statistics are not significant. Therefore, we cannot reject the null hypothesis of no cross-sectional dependence. The cross-sectional dependence test buttresses our choice of the PMG estimator since it incorporates the homogeneity properties of the cross-sections.

To further show the stability of our model and that the PMG results are robust, Fig. 3 presents the normality test of the model. The normality test is performed to confirm whether the residuals of the error terms are normally distributed, the model is specified correctly and the coefficient estimates are efficient and unbiased.

In Fig. 3, the Jarque–Bera test rejects the alternative hypothesis that the series is not normally distributed.

## 5. Conclusion and policy recommendations

This paper empirically examines the relationship between real oil price and economic growth for seven oil-importing low-income countries in sub-Saharan Africa. The panel-ARDL was employed as the estimation technique. The countries included in the study are Ethiopia, Gambia, Mali, Mozambique, Senegal, Tanzania and Uganda. There is an increasing amount of literature that supports the need to perform both symmetric and asymmetric analysis (Salisu and Isah, 2017). Asymmetric effects are therefore investigated by formulating a non-linear Panel-ARDL of the Shin et al. (2014) ARDL model for time series data. We decomposed the real oil price for all the countries and adopted it in the panel form. This approach finds new insights into the relationship between the asymmetries. Particularly, we find that real oil price increase does not have a significant effect on real GDP per capita, while real oil price decrease has a positive effect on real GDP per capita and is consistent with apriori expectation for oil-importing countries. We also conducted the symmetric effects of oil price on growth for comparative analyses.

The symmetric results showed that oil price has a negative impact on real GDP per capita in the long run and is consistent

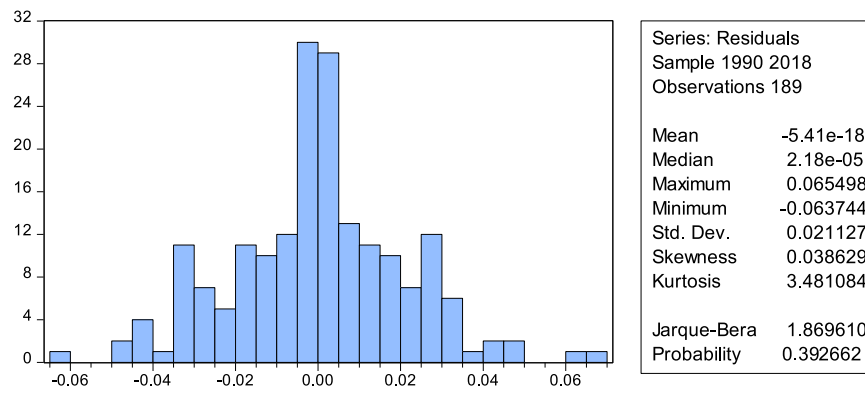


Fig. 3. Normality Test.

with Behmiri and Manso (2013), and Kose Baimaganbetov (2015). However, in the short run, oil price does not have a significant impact on real GDP per capita for the pooled results. Therefore, the negative effect of oil price fluctuations on economic growth is limited to the long run. Therefore, the long-run results support theoretical literature on the impact of oil price on economic growth for oil-importing countries (see Suleiman, 2013; Behmiri and Manso, 2013). However, in the short run, oil price does not have a significant effect on growth. A possible explanation for the findings in the short run may be due to the low level of oil consumption in the energy mix of low-income countries. More so, their labour intensiveness offsets the effect of oil price in the short-run (see Suleiman, 2013; Behmiri and Manso, 2013; Gbatu et al., 2017b). Another explanation is that oil prices are subsidised in SSA countries, therefore the effect of the lower real oil price may not be felt in the short run. World Bank (2018b) explained that only about one-third of SSA countries allow market adjustment to domestic oil prices. Oil prices are usually set by the government. Moreover, Hooker (1996a,b) argued that oil prices do not have a significant effect on economic growth for data that spans beyond the 1980s.

The study also found that oil consumption has a positive impact on economic growth in the long run. The result is in line with the theory that oil consumption stimulates economic growth. Therefore, since oil consumption has a positive effect on growth, it becomes imperative for LIC policymakers to apply technological innovation in the oil sector in order to harness growth from that sector. Stronger energy controls will also help to mitigate against risks associated with oil price fluctuations. Moreover, the productive base of developed countries like the USA limits the potential risks of fluctuations in oil price. It is, therefore, necessary for policymakers in LICs to ensure diversification of revenue generation outside of natural resources through trade, investment incentives, infrastructural development and remittances.

Our results show that a sustained decline in oil price will augment growth and boost the external and fiscal balance of the sample of oil-importing countries. Declining oil prices also provide considerable opportunity to increase savings and reform fuel subsidies, which are substantial in most low-income countries. Lower oil prices provide a favourable environment for fuel and tax reforms with moderate impact on domestic prices paid by consumers. Therefore, for oil-importing developing economies, reduction in the price of oil should support economic growth and improve external and fiscal balances, thereby reducing macroeconomic vulnerabilities associated with commodity price volatilities. On the other hand, a sustained surge in oil prices will negatively impact economic growth. Therefore, we recommend the implementation of economic diversification policy away from oil reliance toward dependence on other sustainable and energy types, especially during periods of oil price surges.

### 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.

### CRediT authorship contribution statement

**Motunrayo O. Akinsola:** Conceptualization, Methodology, Data curation, Writing - original draft, Visualization, Investigation, Software. **Nicholas M. Odhiambo:** Supervision, Validation, Writing - review & editing.

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