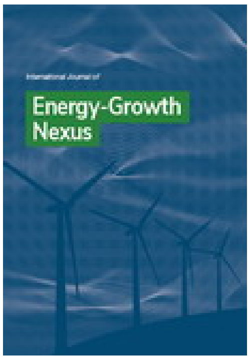

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Oil and growth nexus: fresh evidence from top-ten oil producing countries

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Abstract: Oil as one of the most frequently used categories of energy resources has also been viewed as a critical factor of production coequal to labour and capital. Thus, oil consumption is linked to many economic activities and any energy policies might likely affect this relationship. This study examines the nexus between oil consumption and economic growth by controlling for labour and capital within the framework of a modified aggregate production function in the top-ten oil producing countries in the world during the period 1990–2015. The study applied a recently developed cross-sectional augmented autoregressive distributed lag (CS-ARDL) model and Dumitrescu-Hurlin Granger causality test. The empirical result revealed that oil consumption stimulates economic growth in both short and long run. Similarly, the study shows that capital and labour significantly stimulate economic growth in not only the short but also long run. The causality results also unravelled a feedback causality relationship between oil consumption, labour, and economic growth. However, there is unidirectional causality running from economic growth to capital. Therefore, the policy implication of this study suggests that any oil conservation policies initiated by the government of the top-ten oil producing countries may be detrimental to their economic growth and development.

Keywords: CS-ARDL; economic growth; oil consumption; production function; capital; labour.

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1 Introduction

Interestingly, oil been one of the important and most frequently used energy resources has been widely recognised for its role played as one of the critical factors of production, which in turn boost industrial development. This is not farfetched looking at how production activities in industries, vehicles in the transportation sector, and electricity generation requires substantial amount of oil (Bhusal, 2010). Therefore, the role of energy in any giving economy is critical and also seen by Korkmaz (2022) as the most important components of economic growth (EG). The estimate by the US Energy Information Administration (2020) revealed that the consumption of oil in the last quarter of 2019 was 95.6 million barrels per day which was 6.3 million lower than expected, but rise from the third quarter of 2020 to an average of 92.4 million throughout the year with a marked difference of 8.8 million barrels per day from 2019. However, there is a good expectation that the oil consumption (OC) will rise by more than five million barrels per day in 2021.

However, the degree of oil utilisation by different sectors such transportation, industrial, commercial, residential as well as electric power generations varies across countries and such variations have important policy implications. For instance, when a two-way causal relationship between oil and growth exist, it implies that all policies designed to curtail OC might likely exerts pressure on economic activities. Similarly, when causality run from different directions, policy makers must be cautious because any misapplication of the appropriate policy may stimulates or depress EG (Chu and Chang, 2012). Therefore, understanding the co-movement and direction of causal flow between oil and growth is not only a necessary but sufficient condition for designing and selecting an appropriate energy policy.

Although the path breaking study of Kraft and Kraft (1978) set a stone rolling for the extant empirical studies in the energy economics. But, most of these studies were skewed to energy-growth nexus. Though, few studies have been conducted to unravel the extent to which oil utilisation affect EG, but mostly restricted to bivariate models taking into cognisance the only impact of OC on EG (Yoo, 2006; Žiković and Vlahinic-Dizdarević, 2011; Park and Yoo, 2014; Choi and Yoo, 2016). This reiterate the need for the present study to examines the nexus between oil usage and growth within the context of ten largest oil producers (Brazil, Canada, China, Iran, Iraq, Kuwait, Russian, Saudi Arabia, USA, and UAE) in the world by controlling for capital and labour as determinants of production function. The contributions of this study to the oil-growth nexus literature are as follows; firstly, this study deployed an aggregate production function by adding a distinct role of OC into the production function as against the previous studies such as Bhusal (2010), Žiković and Vlahinic-Dizdarević (2011), Jin et al. (2016) and Sen and Uzunoz (2017). This is because using an augmented production function will solve the problem of omitted variable bias identified with bivariate studies. Secondly, the present study departs from the previous studies by applying cross-sectional augmented autoregressive distributed lag (CS-ARDL) model of Chudik and Pesaran (2015). The approach is applied because of its superiority of accounting all three major importance aspects of panel data modelling which includes dynamics, heterogeneity and cross-sectional dependence (CD) (Bahmani-Oskooee et al., 2019). Also, the application CS-ARDL approach on Ghali and El-Sakka (2004) aggregate production function is robust to omitted variable bias and simultaneous determination of growth regressor (Mohaddes and Raissi, 2017). Thirdly, this study unlike time series or cross-sectional studies can be able to detect and estimate more statistical effect of both common and individual behaviours of groups with more information, variability, and efficiency. Finally, the study employed augmented mean group (AMG) as a robustness check to provide an unbiased and consistent long run estimates as done by Adekoya (2021) and Ibrahim et al. (2022b).

The structure of the paper is configured into five sections including the introduction. Sections 2 and 3 present the literature review and methodology of the study, respectively. Section 4 focuses on interpretation and discussion of the empirical results, while Section 5 presents conclusion and policy implications.

2 Literature review

Studies that unravelled the nexus between oil and growth have reviewed in this section. Therefore, the literature is classified based on time series and panel data studies. For instance, one of the pioneering studies in oil and growth nexus literature is that of Yoo (2006) who unravelled the extent to which OC affect economic growth (EG) in Korea via the aid Johansen developed cointegration test and Granger causality test and concluded that the existence of bidirectional causality between OC and EG. Similarly, Bhusal (2010), Behmiri and Manso (2012), Al-Mulali (2011), Behmiri and Manso (2013), Behmiri and Manso (2014), Park and Yoo (2014) and Choi and Yoo (2016) justified the presence of bidirectional causality test between OC and EG. Similarly, Gyimah et al. (2022) also used Granger causality test to document a bidirectional causality between renewable energy consumption and EG.

However, other studies discovered the existence of unidirectional causality running from OC to EG. For example, Žiković and Vlahinic-Dizdarević (2011), Alkhathlan (2013), Inuwa et al. (2014a), Lim et al. (2014), Ziramba (2015), Terzi and Pata (2016), Saboori et al. (2017) and Waleed et al. (2018). Similarly, Namahoro et al. (2022) showed that causality runs from the positive shocks of renewable energy consumption to EG in Rwanda. Other studies such as Chu and Chang (2012), Jin et al. (2016) and Akinlo (2021) documented the reverse causality running from EG to OC. In addition, Kim and Park (2022) established a causal flow from EG to energy consumption in South Korea. The interaction of energy consumption with the environment and other variables also generates another strand of studies with varying effects. For instance, Ibrahim and Ajide (2021) found that renewable energy, technological progress, and eco-innovation strengthen environmental quality. However, non-renewable energy and trade openness showed a detrimental effect on environmental quality in G-7 countries. Similarly, in 41 Sub-Saharan African countries, Zhang et al. (2022) documented a detrimental effect of non-renewable energy consumption and natural resource rents, and population on environmental quality.

Similarly, Pan et al. (2022) employed a quantile-on-quantile and Granger causality tests to study the effect of nuclear energy consumption on environmental quality in ten countries and established a deteriorating effect of nuclear energy consumption on environmental quality in Spain and China. However, the outcome showed a strengthened influence of nuclear energy consumption on environmental quality. Oke et al. (2021) used system GMM to study the influence of renewable energy on sustainable development measured into economic, social and environmental dimensions and unravelled that renewable energy showed a different effect on different proxies. Ibrahim et al. (2022a) studied the influence of non-renewable energy and technology on quality of life in 43 Sub-Saharan countries and documented that non-renewable energy retard quality of life. However, the coefficient of technology improves quality of life. Yu et al. (2022) deployed the ARDL technique to study the effect of transport infrastructures, output expansion, and renewable energy crude oil imports in China and India. The outcome showed that renewable energy and transport infrastructures retards and stimulates crude oil importation in both countries.

The last category of studies such as Choi and Yoo (2016), Waleed et al. (2018) and Chu and Chang (2012) showed absence of causality relationship between OC and EG. Therefore, the study presents the summary of the most relevant studies in terms the countries included in analysis, methodology used as well as their major findings in Table 1.

Table 1 Summary of empirical studies with their major findings

Author(s)	*Period*	*Countries*	*Methods*	*Findings*
Yoo (2006)	1968–2002	Korea	Johansen developed cointegration method and Granger causality test	Unravelled a bidirectional causality between OC and EG in the long run.
Bhusal (2010)	1975–2009	Nepal	Johansen developed cointegration test and Granger causality test	Unravelled a bidirectional causality between OC and EG in long and short run.
Fuinhas and Marques (2012)	1965–2009	Portuguese	ARDL bound test	OC and oil prices stimulate OG in both short and long run.
Park and Yoo (2014)	1965–2011	Malaysia	Johansen cointegration technique and Granger causality test	Bidirectional causality between OC and EG in long and short run.
Lim et al. (2014)	1965–2012	Philippines	Johansen developed cointegration technique and Granger causality test	Causality run from OC and CO_2 emissions to EG.
Inuwa et al. (2014b)	1980–2011	Nigeria	Johansen developed cointegration test and Granger causality test	Causality runs from OC to EG.
Inuwa et al. (2014a)		Nigeria	ARDL bound test	OC positively and significantly stimulate EG.
Ziramba (2015)	1970–2008	South Africa	Engle and Granger cointegration technique and Toda and Yamamoto test	Causality runs from OC to EG, but bidirectional causality between capital to EG.
Terzi and Pata (2016)	1974–2014	Turkey	Engle-Granger and Gregory-Hansen techniques, and Granger causality test	Causality runs from OC to EG.
Choi and Yoo (2016)	1965–2010	Brazil	Johansen developed cointegration technique and Granger causality test	Bidirectional causality between OC and EG in the long run. But, no causal relation was observed in the short run.

Table 1 Summary of empirical studies with their major findings (continued)

Author(s)	*Period*	*Countries*	*Methods*	*Findings*
Jin et al. (2016)	1965–2011	Ecuador	Johansen developed cointegration test and Granger causality test	Causality runs from OC to EG in both short and long run.
Waleed et al. (2018)	1965–2015	Pakistan	Johansen developed cointegration method and Granger causality test	Causality runs from OC to EG only in the long run. However, the study did not unravel the causal relation between OC and EG in the short run.
Alkhathlan (2013)	1971–2010	Saudi Arabia	ARDL bound test	Oil revenue stimulate EG in both short and long run.
Bunnag (2021)	1971–201	Thailand	ARDL bound test and Granger causality test	Causality runs from OC to EG and CO_2 emissions.
Žiković and Vlahinic-Dizdarević (2011)	1993–2007 and 1980–2007	Small European countries	Johansen developed cointegration test and Granger causality test	Mixed causality between OC and EG.
Behmiri and Manso (2012)	1976–2009	37 OECD	Pedroni cointegration technique, fully modified ordinary least square (FMOLS), and panel Granger causality test	OC positively stimulate EG, while bidirectional causality between OC and EG.
Al-Mulali (2011)	1980–2009	Middle East and North Africa (MENA)	Pedroni cointegration test, Johansen Fisher panel cointegration technique and panel Granger causality test	Bidirectional causality exists between OC and EG, CO_2 emissions and EG.
Chu and Chang (2012)	1971–2010	G-6	Bootstrap Granger causality test	Unravelled a bidirectional causality between nuclear consumption and EG in Japan, the UK, and the USA. However, absence of causal flow between OC and EG in France, Germany, Canada, and the UK.
Behmiri and Manso (2013)	1985–2011	23 SSA countries	Pedroni developed cointegration test, FMOLS, and panel Granger causality test	Feedback causal relation between OC and EG in both periods.

Table 1 Summary of empirical studies with their major findings (continued)

Author(s)	*Period*	*Countries*	*Methods*	*Findings*
Behmiri and Manso (2014)	1980–2012	20 Latin American countries	Pedroni developed cointegration test, fully modified OLS, and panel Granger causality test of vector error correction model (VECM) framework	OC positively stimulate EG and feedback causal relation between OC and EG in the short run only.
Akinlo (2021)	1980–2016	Nigeria	NARDL, VECM, and Hatemi-causality test	Causality runs from petroleum consumption to EG.
Namahoro et al. (2022)	1990–2015	Rwanda	NARDL	Causality of positive shocks of renewable energy consumption runs to economic growth.
Kim and Park (2022)	1971–2014	South Korea	Linear causality test	One-way causality running from EG to energy consumption.
Adekoya (2021)	1990–1997	16 resource rich and poor countries	Panel ARDL and AMG	OC is found to have stimulated EG in the resource-rich in the short run but decrease in the long run. However, there is no significant evidence that OC stimulate EG.
Gyimah et al. (2022)	1990–2015	Ghana	Granger causality test	Two-way causal flow between renewable energy consumption and EG.
Korkmaz (2022)	1992–2018	Russian Federation	ARDL	Oil, gas, and coal consumption did not stimulate EG in long run.
Khan et al. (2022)	1990–2020	Germany	ARDL	Renewable energy consumption and transport services have stimulated economic growth. Similarly, digital divide and carbon emissions also enhance economic growth.
Inuwa et al. (2019)	2007–2016	ECOWAS member countries	Difference and system GMM	Electricity consumption, capital and labour positively and significantly influence output expansion.

Table 1 Summary of empirical studies with their major findings (continued)

Author(s)	*Period*	*Countries*	*Methods*	*Findings*
Azam et al. (2023)	1990–2017	30 developing countries	Static panel techniques and Dumitrescu-Hurlin causality tests	Primary energy consumption, gross capital formation, financial development and institutional quality influence economic growth.

The preceding paragraphs alongside Table 1 present the existing empirical studies conducted directly or indirectly relevant to the present study. It is apparent that most of the earlier studies are not only restricted to the time series modelling framework but also focus on bivariate analysis so that the problem of omitted variables bias cannot be ruled out. Secondly, it is also unravelled from the existing studies that employed panel data were mostly limited to first generation methodologies that cannot handle CD even if it is present. Thus, inferences drawn while neglecting the possibility of CD issues might be spurious. Thirdly, this study is the first to the best of the authors' knowledge to examine the oil-growth nexus in the top-ten oil producing countries in the world. This study therefore resolves the aforementioned lacunas by employing the second generation methodologies in the form of CS-ARDL model that is not only robust to endogeneity complications but also produce efficient results in the presence heterogeneous slope and CD issues. To further strengthen the results, the study employed AMG as a robustness check.

3 Methodology

3.1 Data

The main aim of this study is to re-examine the oil and growth nexus in the ten largest oil producers in the world using the annual data spanning from 1990–2015. The countries include Brazil, Canada, China, Iran, Iraq, Kuwait, Russian, Saudi Arabia, USA, and UAE. Specifically, the data were sourced from the World Development Indicators (WDI) of the World Bank (2019) include GDP per capita (GDPP), labour force (LABF), and gross fixed capita formation (GFCF). However, the data on OC (OILC) OC is obtained from the US Energy Information Administration (EIA). The GDP per capita and Gross fixed capital formation stand for EG and capital measured in constant 2010 US$, respectively. OC and labour measured by thousand barrels per day and labour force, respectively.

3.2 Model

Following the pioneering study of Ghali and El-Sakka (2004) where the authors proposed a framework based on a neo-classical one-sector aggregate production function. This study followed the works of Lee and Chang (2008), Inuwa et al. (2016), Lee and Chien (2010), Wolde-Rufael (2009) and Salamaliki and Venetis (2013) to adopt this model as a working framework to unravel the nexus between OC and EG, since it has been established that energy is an essential factor of production. This is because the modern method of production requires substantial amount of oil that will boost output, which invariably stimulates EG. As such it is expected to have a positive impact on EG. Similarly, capital and labour as conventional factors of production are expected to positively influence EG (Lee and Chien, 2010; Inuwa et al., 2016). The study adopts the following modified production function where OC, capital, and labour are separate factor inputs as follows:

$$GDPP_t = f\left(OILC_t, GFCF_t, LABF_t\right) \tag{1}$$

where *GDPP* is GDP per capita, *OILC* is OC, *GFCF* is capital stock, and *LABF* is and labour. The log linear form of equation (1) is express as:

$$LGDPP_{i,t} = \beta_0 + \beta_1 LOILC_{i,t} + \beta_2 LGFCF_{i,t} + \beta_3 LLABF_{i,t} + \mu_{i,t} \tag{2}$$

where $i = 1, \ldots, N$ stands for the number of countries as cross-sectional units in the panel and $t = 1, \ldots, T$ for each time period. The *LGDPP* stands logarithm of GDP per capita of country; β's are parameter estimates; β_0 is the intercept; *LOILC* represent OC; *LGFCF* stands for gross fixed capital formation; *LLABF* denotes labour force; and $\mu_{i,t}$ is the error term which is assumed to be distributed independently in all time periods of the country *i*. It is worth stressing that all the variables are transformed into logarithm.

3.3 Estimation strategy

3.3.1 Panel unit root and cross-sectional dependency tests

The recent development of panel data modelling begins by checking the dependency among countries, so that policy truncation would be avoided. This can easily happen because of increasing globalisation and unobserved common shocks. Therefore, the study applied CD test of Pesaran (2004) where the null hypothesis of the uncorrelated individual time series within the panel are tested against the correlated individual errors terms within that panel in the form of alternative hypothesis. The CD test equation is specified as follows:

$$CD = \sqrt{\frac{2T}{N(N-1)}\left(\sum_{i=1}^{N-1}\sum_{j=i+t}^{N}\widehat{p_{ij}}\right)N(0,1)} \tag{3}$$

where the countries and years of observations are denoted by *N* and *T*, respectively. While the combined correlated residuals of the approximated model is represented by p_{ij}. To circumvent the complications of CD issue, the study applied the second generation cross-sectional augmented Dickey-Fuller (CADF) unit root test. It is computed as follows:

$$\Delta y_{it} = \alpha_i + \rho_i y_{it-1} + \beta_i \overline{y}_{t-1} + \sum_{j=0}^{\lambda} \gamma_i \Delta\overline{y}_{it-1} + \sum_{j=0}^{\lambda} \delta_i \Delta\overline{y}_{it-1} + v_{it} \tag{4}$$

where α_i stands for deterministic term, λ denotes the lag order, $\overline{y}_t$ is the cross-sectional mean of time *t*. Following equation (4) specified above, individual *ADF* statistics are computed based on *t*-statistics. Similarly, the study averaged the CADF statistic to produce CIPS for each *i* as developed by Pesaran (2007):

$$CIPS = \left(\frac{1}{N}\right)\sum_{i=1}^{N} t_i(N, T) \tag{5}$$

3.3.2 Cointegration test

The next step after checking the unit root tests is to investigate the possibility of their co-movement in the long run. This has been checked using Westerlund (2007) cointegration test. This technique has the ability to overcome the challenges posed by both slope heterogeneity and CD among the models. The test statistics are structured into group and panel statistics. The null hypothesis posited that all the cross-section units in the panel are not cointegrated are tested against all the cross-section units are cointegrated tagged as alternative hypothesis.

3.3.3 CS-ARDL model

The study applied the CS-ARDL model of Chudik and Pesaran (2015). This framework solved the problem of CD by including the lagged of dependent variables in order to capture the dynamic behaviour of weakly exogenous regressor. Similarly, the methodology is applied in the presence of variables having stationary at level, first difference or even mutually integrated but the point worth noting is that none of the included variables in the study are integrated of order two. It also solve the problem of endogeneity in growth equations (Vedia-Jerez and Gallo, 2015; Zhao et al., 2022). In addition to the capacities to explain the short run dynamics by the CS-ARDL error correction term, the framework also solves the complications posed by unobserved effect in not only the short but also long run. Thus, the specified equation of the model is given as:

$$\begin{aligned} LGDPP_{it} = {} & \mu_i + \theta_i\left(LGDPP_{it-1} - \beta_i X_{it-1} - \psi_{1i}\overline{LGDPP}_{t-1} - \psi_{2i}\bar{X}_{t-1}\right) \\ & + \sum_{j=1}^{\partial-1}\omega_{ij}\Delta LGDPP_{it-j} + \sum_{j=0}^{\ell-1}\omega_{ij}\Delta X_{it-j} + \lambda_{1i}\overline{LGDPP}_t + \lambda_{2i}\bar{X}_t + \varepsilon_{it} \end{aligned} \tag{6}$$

where $LGDPP_{it}$ is the explained variable, the X_{it} in the model stands for all explanatory variables spanning the long run, $\bar{X}_{t-1}$ is the long run average of explanatory variables, $\overline{LGDPP}_{t-1}$ denotes the long run average of explained variable, $\Delta LGDPP_{it-j}$ is the short run explained variables, ΔX_{it-j} stands for the explanatory variables in the short run, $\overline{LGDPP}_t$ is the mean of explained variable during the short run, $\bar{X}_t$ is the average of explanatory variables during the short run, and ε_{it} is the error term. *j* and *t* represent the cross-sectional and time dimensions $j = 1, \ldots, J$, and $t = 1, \ldots, T$, respectively. β_i denotes the coefficients of explanatory variables, ω_{ij} and ϖ_{ij} are the short run coefficient of dependent and independent variables, λ_{1i} represents mean of dependent variable, and λ_{2i} and represents the mean of explanatory variables.

3.3.3.1 Dumitrescu-Hurlin panel causality test

In order to examine the direction of the causal flow between OC and EG in the ten largest oil producers in the world, the study applied the recently developed Dumitrescu-Hurlin panel Granger causality test. This test is applied because of its flexibility of accommodating larger number of cross-sections than time period ($N > T$) and larger time period than number of cross-sections ($N < T$) as posited by Haseeb et al. (2018). Interestingly, the test has the capacity to circumvent the issue of cross-sectional dependency among the countries (Dogan and Seker, 2016; Wang et al., 2021). The test is conducted using the following linear model:

$$LGDPP_{i,t} = \alpha_i + \sum_{j=1}^{j} \delta_i^{(\phi)} LGDPP_{i,t-j} + \sum_{j=1}^{j} \chi_i^{(\phi)} LOILC_{i,t-j} + \mu_{i,t} \tag{7}$$

where α_i represents a constant term, $\delta_i^{(\phi)}$ and ϕ represent the lag parameter and its length, respectively, $\chi_i^{(\phi)}$ stands for slope coefficient and finally, the cross-sectional difference in the units are denoted by $\delta_i^{(\phi)}$ and $\chi_i^{(\phi)}$. Therefore, the null hypothesis stating the absence of causality relationship in the panel is tested against its alternative that states that the causality relationship exists in the panel. But the point worth noting is that the Wald statistics to be used when time period is greater than number of cross-sections as suggested by Dumitrescu and Hurlin (2012) is expressed as follows:

$$Z_{N,T}^{Hnc} = \sqrt{\frac{N}{2K}} \left(Z_{N,T}^{Hnc} - K \right) \tag{8}$$

4 Empirical results and discussion

The duo most likely problems of panel data analysis in recent time are tests for cross-sectional dependency and slope heterogeneity, which need to be checked before examining any relationship between variables. This is not farfetched looking at how world turned to a small village with the aid of globalisation, that is measures taken in one economy may truncate to some nearby countries as well. Similarly, the choice of either first or second generation panel methods depends on the presence or otherwise of cross-section dependence among the countries in the panel (Ahmad et al., 2020; Erum and Hussain, 2019). Therefore, the study applied Pesaran (2004) CD test and Table 2 displayed the results. The findings revealed the rejection of the null hypothesis suggesting the independence among the cross-sectional units. In other words, the study established dependence of cross-sectional units on one another, which implies that any change in any of the variable in one of the countries may likely affect the other countries.

To check whether ten largest oil producing countries do have heterogeneous slope coefficients due to varying degrees of growth and development, the study utilised slope heterogeneity test and Table 3 displayed the results. The results unravelled the existence of heterogeneity in the data indicating the variability of the slope among the countries in the panel. This implies the rejection of the null hypothesis suggesting the slope homogeneity among the panel.

Table 2 Results of CD test

Variable	*CD*	*P-value*
LGDPP	15.32***	0.000
LOILC	6.93***	0.000
LLABF	18.99***	0.000
LGFCC	2.37**	0.018

Notes: *** and ** stand for significance level at 1%, and 5%, respectively.

Table 3 Results of slope heterogeneous test

Test statistics	*Value*	*P-value*
$\tilde{\Delta}$	9.054***	0.000
$\tilde{\Delta}$ adjusted	10.074***	0.000

Notes: *** stands for the significance level at 1%.

The results from both cross-sectional dependency and slope heterogeneity tests recommend the application of the second generation methodologies since establishing the existence of cross-sectional independence among the variables rendered most of the first generation panel methodologies inefficient and inadequate (Ahmad et al., 2020). Therefore, the study applied both CADF and CIPS unit root tests. These tests have the capacities to produce robust and efficient results even in the presence of cross-section dependence among the variables and the outcome of the tests are displayed in Table 4. Therefore, the results of the tests revealed that most of the variables have unit root in their level values, but became stationary after taking their first difference. This implies that the variables under study are all integrated of order one, i.e., *I*(1) with the exception of gross fixed capital formation.

Table 4 Results of unit root tests

	Pesaran (2007) CADF		
Variable	*At level*	*At first difference*	*Remark*
LGDPP	–1.682	–2.730***	*I*(1)
LOILC	–1.743	–2.736***	*I*(1)
LLABF	–1.529	–2.423**	*I*(1)
LGFCC	–2.075	–2.374*	*I*(1)
	Pesaran (2007) CIPS		
Variable	*At level*	*At first difference*	*Remark*
LGDPP	–1.973	–3.214***	*I*(1)
LOILC	–1.745	–4.593***	*I*(1)
LLABF	–1.529	–2.423**	*I*(1)
LGFCC	–2.936***	–3.909***	*I*(1)

Notes: ***, ** and * indicate the significance level at 1%, 5%, and 10%, respectively.

The results of bootstrapped Westerlund (2007) panel cointegration test are displayed in Table 5. The results revealed that the null hypothesis of no cointegration from the mean group statistics is rejected implying the presence of long run equilibrium among the variables at 1% level of significance. Similarly, the results from panel statistics also revealed the rejection of null hypothesis indicating that all the variables co-move together in the long run.

Table 5 Results of Westerlund panel cointegration test

Test statistics	*Value*	*Z-value*	*Robust P-value*
G_t	–2.780***	–1.420	0.000
G_a	–10.408***	0.195	0.000
P_t	–8.418***	–3.514	0.000
P_a	–16.410***	–3.343	0.000

Notes: *** represent the significance level at 1%.

Table 6 Results of CS-ARDL

Variable	*Coefficient*	*Standard error*	*Z-value*	*P-value*
		Short run results		
LOILC	0.2906898**	0.1371677	2.12	0.034
LLABF	0.7179807***	0.2405435	2.98	0.003
LGFCC	0.1533446**	0.0698756	2.19	0.028
ECM(–1)	–0.5124465***	0.066833	–7.67	0.000
		Long run results		
$LRGDP_{t-1}$	0.4875535***	0.066833	7.30	0.000
LOILC	0.1684326**	0.0750635	2.24	0.025
LLABF	0.3044409***	0.081786	3.72	0.000
LGFCC	0.0680925**	0.0303294	2.25	0.025

Notes: *** and ** stand for the significance level at 1%, and 5%, respectively.

Table 7 AMG – robustness test

Variable	*Coefficient*	*Standard error*	*Z-value*	*P-value*
LOILC	0.5571871***	0.1962829	2.84	0.005
LLABF	0.5706331*	0.311827	1.83	0.067
LGFCC	0.1286472***	0.044603	2.88	0.004
Constant	1.293108	6.230823	0.21	0.836

Notes: *** and * stand significance level at 1%, and 10%, respectively.

The preceding bootstrap cointegration test showed the presence of long run equilibrium relationship among the studied variables, the study applied CS-ARDL to examine the extent to which oil utilisation, labour force, and gross fixed capital formation affect EG in not only the short but also the long run. The result is presented in Table 6. The result of both short and long run established that OC positively and significantly stimulates EG at 5% level of significance. Thus, a 5% rise in OC will stimulates 0.29% and 0.17% rise in EG, respectively. This result supports the results of Behmiri and Manso (2012, 2013, 2014), Fuinhas and Marques (2012), Apergis and Payne (2011), Adekoya (2021) and

Azam et al. (2023). However, this finding is contradicted by the study of Korkmaz (2022) who established that OC did not stimulate EG. Similarly, the coefficient of labour force evidenced a positive and significant effect on EG in not only short but also long run. This suggests that a 1% rise in the labour force will stimulate EG to rise by 0.72% in the short and 0.30% in the long run. This finding corroborate with the studies of Lee and Chang (2008), Inuwa et al. (2016), Apergis and Payne (2009) and Inuwa et al. (2019). Furthermore, the coefficient of gross fixed capital formation has also been found to have influenced EG positively in not only short but long run. This suggest that 5% rise in gross fixed capital formation will influence EG by 0.15% and 0.07%, respectively. This finding corroborate with that of Apergis and Payne (2010), Al-Mulali and Ozturk (2014), Inuwa et al. (2019) and Azam et al. (2023). Finally, the coefficient of ECM is found to have been rightly singed and significant indicating a fair of convergence toward the long run equilibrium (–0.51). This has confirmed the earlier findings of cointegrating relationship among the studied variables.

To check for robustness of the CS-ARDL findings presented in Table 6, the AMG result is displayed in Table 7. The findings evidenced that all the coefficients of OC, labour force, and gross fixed capital formation have been found to have stimulated EG positively and significantly. These findings corroborated with that of CS-ARDL findings.

Presence of cointegrating relationship among the studied variables indicates the presence of causality among the variables in at least one direction. To confirm this, the study made us of Dumitrescu-Hurlin (D-H) panel causality test and outcome are showed in Table 8. The outcome revealed bidirectional causal relationship between OC and EG. This result supported the findings obtained by Yoo (2006), Al-Mulali (2011), Park and Yoo (2014), Behmiri and Manso (2011, 2012, 2014), Lim et al. (2014), Choi and Yoo (2016) and Waleed et al. (2018). In contrast, the finding has been challenged by the studies of Kim and Park (2022), Namahoro et al. (2022) and Azam et al. (2023). This indicates that any conservation policy will have negative consequences on the EG of their countries. Similarly, the outcome unravelled a bidirectional causal relationship between labour force and EG. It implies a two-way causality between the variables and results supports studies of Shahiduzzaman and Alam (2012), Pao and Fu (2013) and Rahman et al. (2020). However, the study established a one-way causal flow running from EG to gross fixed capital formation without feedback.

Table 8 Dumitrescu-Hurlin panel causality tests

Null hypothesis	*W-statistic*	*Zbar-statistic*	*P-value*
LGDPP does not Granger-cause *LOILC*	5.8050***	4.6602	0.0000
LOILC does not Granger-cause *LGDPP*	5.7573***	4.6017	0.0000
LGDPP does not Granger-cause *LLABF*	4.0044**	2.4548	0.0141
LLABF does not Granger-cause *LGDPP*	6.5950***	5.6277	0.0000
LGDPP does not Granger-cause *LGFCC*	5.2307***	3.9568	0.0001
LGFCC does not Granger-cause *LGDPP*	1.9383	–0.0756	0.9397

Notes: *** and ** denotes the significance level at 1%, and 5%, respectively.

5 Conclusions

The contribution of oil to both the industrial sector and domestic consumption in the global economy cannot be overemphasised. This is not farfetched looking at the significant roles it plays in the EG of both developed and developing countries in the last few decades. Thus, this study examines the nexus between oil and growth in the top-ten oil producing countries in the world during the period 1990–2015. The study utilised the second generation panel methodologies capable of handling CD. The results of both Pesaran (2004) CD and Pesaran and Yamagata (2008) slope homogeneity tests revealed the existence slope heterogeneity and CD among the top-ten largest oil producing countries, respectively. Similarly, the results of CADF and CIPS unit root tests showed that most of the variables are stationary after taken their first difference. This has given the study the room to apply Westerlund cointegration and augmented cross-sectional autoregressive distributed lag (CS-ARDL) tests.

Empirical results from the bootstrap Westerlund panel cointegration test showed the existence of long run equilibrium relationship among the studied variables. Also, the results of the short and long run from CS-ARDL revealed that OC, labour and capital have been found to have stimulated EG, which have also been checked and robustly confirmed by AMG. The results of Granger causality from Dumitrescu-Hurlin unravelled that there is bidirectional causality relationship between OC and EG. Similarly, the test evidenced a two-way causality relationship between labour and EG. However, causality only runs from EG to capital without feedback. Therefore, the policy implication of this study suggests that any oil conservation policies initiated by the government of the top-ten oil producing countries may be detrimental to their EG and development. Therefore, the study recommends that policy makers in the studied countries should design long term energy policies capable of stimulating sustainable growth through the use of energy efficient technologies. Since the study unravelled the significant effect of gross fixed capital formation on EG, the study also recommends the provision of not only a conducive but also enabling environment for gross fixed capital formation to thrive. This can be achieved through unprecedented increases in savings by both households and the government that would generate surplus capital which in turn stimulated investment that would lead to growth and development. Finally, policies designed to create sound and efficient labour force that would promote and sustain production that would stimulate EG should be implemented.

The outcomes from the present study have some limitations that can be addressed by future studies. This study is limited to top-ten oil producing countries; therefore future studies can explore the effect of OC in the top-ten oil consuming countries so that comparison of the impact can be easily made. Secondly, other types of non-renewable energy such as natural gas, coal, and electricity should also be considered in their major producing countries in the world. Finally, the need for distributional and heterogeneous effects of OC across quantiles via the recent method of moments quantiles regression (MMQRE) as against the conventional mean approach opens the possibility of future research.

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