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Effect of gas flaring, oil rent and fossil fuel on economic performance: The case of Nigeria

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ABSTRACT

The study investigates the effect of gas flaring, oil rent and fossil fuel on economic growth in Nigeria from 1990 to 2019 using the autoregressive distributed lag error correction (ARDL-ECM) representation. The fully modified ordinary least squares (FMOLS) and Canonical cointegration regression (CCR) methods are used to check for robustness of the estimates. From the ARDL-ECM results, the study highlights that in the long-run there is significant positive contribution of oil rent, gas flaring and fossil fuel production. For the most part, the outcomes of the FMOLS and CCR align with our findings except that gas flaring showed to depress economic performance. Following these, we sustain the argument that the oil-led and fossil-led growth hypotheses hold. Thus, both the oil sector and use of fossil energy are the major drivers of economic activities in Nigeria. We therefore conclude that, within the scope of our study, natural resource curse or Dutch disease hypothesis is not validated. The authors recommend that the economic gains from Nigeria's rich natural endowments be consolidated through well thought-out diversification programs for economic sustainability. Appropriate policies should also be developed and implemented towards incremental reduction, and ultimate elimination of gas flaring.

1. Introduction

Sustainable consumption and production is an essential component of the 17 Sustainable Development Goals (SDGs) defined by the United Nations (UN, 2019). It is the creation and utilization of goods and services in a socially, environmentally and economically beneficial manner such that ability to meet the needs of the present does not compromise capacity to meet the needs of the future. Flaring of gas is a standard practice for gas pressure control, and facility safety measure in most process plants such as refineries, oil production platforms and petrochemicals. In this system, the excess gas collected by various units is burnt-off in a flare stack (Tofighi and Abedian, 2016). Mitigation of the environmental impact of gas flaring involves commitment of huge financial resources which could have been deployed to the productive sector for output growth. As a country that relies heavily on oil revenue to fund its policies and programmes, the implication is that inflows from oil exports are used to clean up the environment rather than expanding the capacity for secondary production that should produce sustainable growth.

In spite of its undisputable contribution to global greenhouse gas emissions, flaring and venting of associated gas during oil production is still common practice among oil producing nations. PWC (2020) showed that total revenue lost by Nigeria from gas flaring in 2018, obtained from DPR annual reports, NNPC and PWC analysis is put at 233.05 billion naira (stated in local currency) while cost of rejuvenating the polluted environment, as stated by the National Environmental Economic and Development Study (NEEDS) for Climate Change in Nigeria, for 2018 is 22.76 billion naira. It further reveals the estimated value-addition that could have accrued to the economy from derivatives of flared gas during the same period as USD 2.73 ($2.73) billion. Flaring therefore constitutes an inefficient use of energy resources, presents health risks, and contributes to climate change (Willyard, 2019). Not only does it

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constitute a colossal economic waste, it also promotes harmful practices that degrade the ecosystem. What a waste of valued national natural asset.

Exploitation of natural resources is known to produce two opposite effects. Firstly, it increases the country's income and; secondly, it triggers the process of deindustrialization as new investment decisions become skewed in favour of the natural resource sector. This leads to rent-seeking behaviour with associated corrupt practices that depress economic performance. Though crude oil production has enormous capacity to drive expansion of economic activities and spur inclusive development in oil-rich countries, research has shown that resource-dependent economies experience negative growth, and develop at a slower pace than resource-poor nations (Ike et al., 2016). The authors argue that investment in natural resources stifles the industrial and agricultural sectors (crowding-out effect), leading to rapid deindustrialization and ultimately economic contraction. In addition, weak institutions and rent-seeking practices of corrupt public officials have been identified as impediments to the use of natural resources to fast-track economic growth and development (Kaznacheev, 2013; Malattah and Malattah, 2016). These studies suggest that natural resource-abundance does not automatically confer prosperity status on citizens, and that poverty may thrive even in the midst of plenty.

Nigeria's over fifty years of experience in oil trade has shown that oil exports alone do not automatically turn poor countries into prosperous economies. Hitherto, many experts believe that hydrocarbon abundance would produce wealth and economic growth. Today, the expectations are much more restrained (Khalili-Garakani et al., 2021). Oil exporters are paradoxically abundant but in reality very poor, an indication of King Mida's problem or what OPEC founder Juan Pablo Perez Alfonso once called the result of the devil's excrement because of problems associated with petroleum. Some oil-dependent countries, which Nigeria clearly exemplifies, are among the most economically disadvantaged and conflict-ridden societies in the world. Why should a hydrocarbon resource-rich country be affected so much by the "paradox of the plenty"? Should natural resource abundance not be a blessing rather than a curse? Estimates showed Nigeria natural gas reserve could last for about 110 years while the crude oil for 37 years respectively. Additionally, Fawole et al. (2016) estimated the daily natural gas production in Nigeria to be 5.78 m cubic feet of which as large as 80% is flared, 12% re-injected leaving as little as 8% for domestic, industrial, and export markets. Furthermore, out of the 208.4 trillion cubic meters of proven world gas reserve, Nigeria account for about 2.5%. Thus, Nigeria has been described as more of natural gas province than oil. Literature has shown that in 2003 about 2.5 standard cubic feet of natural gas equivalent to 25% of the UK natural gas consumption estimated to worth US $2.5 billion was flared daily. The economy of Nigeria was anchored on the agricultural sector prior to commercial crude oil discovery in 1956 in Oloibri, a remote swampy village in the Niger Delta Region (NDR) of southern Nigeria (Nnaji et al., 2012). The development and growth of the oil industry shifted the focus from agriculture to crude oil and crude oil drilling is associated with the production of large quantity of associated natural gas, now seen as a liability rather than an asset (Uzoekwe, 2019).

The crude oil industry accounts for over 20% of Nigeria's GDP, 95% of foreign exchange earnings, and approximately 65% of budgetary revenues (FOE, 2004). According to Energy Information Administration (EIA), the production of about 1.2 trillion cubic feet of dry gas in 2012 made the Nigeria the 25th global natural gas producer. However, most natural gas produce in the country is burnt or flared into the atmosphere resulting in negative environmental consequences. This practice account for about 11.34% of 134 billion cubic feet of annual global natural gas flaring estimated by World Bank in 2010. Aside from the negative environment externalities, there are enormous economic losses associated with natural gas flaring. Nigeria National Petroleum Corporation (NNPC) quoted $1.705 billion (272.8 billion naira) as the estimated loss by Nigeria through flaring about 409.311 billion standard cubic feet of natural gas in the 2013 fiscal year. Nigeria lost an estimated N192.22bn from January to November 2020 as international oil companies and local players flared a total of 198.12 billion standard cubic feet of natural gas. Also, Nigeria lost an estimated N53.26bn (at $3.93 per 1, 000scf) in the first two months of 2021 as international oil companies and local players flared a total of 33.04 billion standard cubic feet of natural gas. The loss of revenue from natural gas flared to the environment has devastating effects on ability to carry out development actions, finance infrastructures or, just maintain basic public services (Adole, 2011; Giwa et al., 2019).

In view of the declining economic and social performance indicators in Nigeria *vis-a vis* its rich natural resource endowments, we see a compelling need to test the resource-curse syndrome for Nigeria by analyzing how the activities of the oil sector affect overall economic performance in the country based on data spanning the period 1990–2019. Not many studies in economic literature, particularly in the context of developing oil-rich countries, have considered the joint influence of oil rent, gas flaring and fossil fuel production on economic performance. In addition, evidence from reviewed literature indicates mixed results in relation to the interaction between economic growth and the explanatory variables, implying that the economy responds differently to macroeconomic fundaments across different jurisdictions and across different time horizons. This has important implications for macroeconomic planning for individual countries, as it does not show support for "one cap fits all" policy. The rest of the paper is structured as follows: Section 2 reviews the extant literature; Section 3 outlines the data and methodology; Section 4 details the results and discussions; and Section 5 concludes with policy recommendations.

2. Review of related literature

2.1. Theoretical background

Ideally, it is expected that natural resource abundance should drive rapid economic growth and development as espoused by proponents of the Staples theory (MacKintosh, 1967; Sid-Ahmed, 1989). Advocates of the theory argue that natural resource exports significantly account for the rapid transformation of economies like Chile (Davis, 1995), Norway and Indonesia (van der Ploeg, 2011). However, that is not always the case. Quite a lot of resource-rich countries rank among the poorest nations of the world. The theoretical foundation for this paradox was laid in the work of a French philosopher, Jean Bodin, (reprinted in 1962) which indicates that easy riches lead to sloth. Bodin argued that men of a fat and fertile soil are often effeminate and cowards, but a barren country produces men who are temperate by necessity, and as a result more careful, vigilant and industrious (Bodin, 1962 cited by Holmes, 1995). This implies that free or cheap money kills enterprise.

The Dutch disease and resource curse hypotheses have also been used in economic literature to explain this paradox. The Dutch disease hypothesis states that natural abundance can hinder the development of important tradable sectors like manufacturing, agriculture, etc. when vital production inputs like labour and capital are concentrated on development and exploitation of natural resources while neglecting to diversify to other economic sectors. They also argue that since primary products obtained from natural resources are price-sensitive, they render resource-dependent nations vulnerable to global market volatilities. Prior to the discovery of oil in Nigeria in 1956, agriculture was the mainstay of the economy but today the country is both a major oil-producer and a major importer of secondary (manufactured and industrial) products, in addition to agricultural products, having relegated agriculture to the background. Related to the above is the resource curse hypothesis which contends that resource abundance may not necessarily be blessing, as agitations for ownership and control may often generate strife among communities and groups. It may also promote rent-seeking and corrupt practices, weaken institutions and stifle enterprise, and hence productivity. In the oil producing Niger Delta area of Nigeria, conflicts and heightening insecurity arising from agitations and struggle for ownership and control of oil resource are very rampant, leading to destruction of production facilities and installations and ultimately disruption of production targets.

2.2. Theoretical/contextual review

To contextualize the issues in this research, theoretical issues and empirical studies are reviewed, organized and discussed thematically for easy flow and understanding of the subject under investigation. Within the context therefore, we organized reviewed literature around topics or issues, rather than progression of time. In this regard, literature on the nexus of economic growth and each explanatory variable are presented in the following sub-sections:

2.2.1. Gas flaring and economic growth

Gas flaring refers to the combustion of associated gas generated during various processes including oil and gas recovery, petrochemical process, and landfill gas extraction. According to Thurber (2019), the necessity for flaring often comes to the fore when natural gas is produced as a by-product of oil extraction and there is no infrastructure to put it to productive use. Nigeria is hugely endowed with abundant natural deposits but a great proportion of this vital resource occurs as associated gas (Abdulhakeem and Chinevu, 2014). According to the World Bank (2020), the necessity for flaring associated gas derives from regulatory, economic or technical obstacles to gas market development, or inability of existing infrastructure to support its profitable exploitation, or impossibility of re-injecting associated gas back into the reservoir.

Gas flaring has both economic and environmental implications for macroeconomic performance. It contributes to environmental degradation through carbon-dioxide and carbon-monoxide emissions from incomplete combustion of associated natural gas (Elvidge et al., 2007; Buzcu-Guven et al., 2010). These emissions have been linked to the preponderance of severe respiratory diseases, cancer and premature death common in oil producing regions (ERA, CJP/FOE, 2005). A major fall-out of the environmental implication of gas flaring is the colossal loss of financial resources associated with environmental cleaning, procurement of medicare, and ultimately loss of human capital.

An estimated 140 billion cubic meters of gas is flared globally every year across the oil-producing nations (McGreevey and Whitaker, 2020). Nigeria ranks among the top 10 gas flare nations, with an estimated 7.4 billion cubic meters of gas flared in 2018 and about 425.9 billion cubic meters flared in 2019 (Eboh, 2019). With relevant infrastructure in place, this resource could be harnessed and deployed to power generation, among other vital uses, required to drive economic growth. On the environmental cum socio-economic implications of gas flaring, PWC (2019) estimates an annual average cost of about 28.8 billion naira (in local currency) on the Nigerian economy, in addition to incidental issues associated with noise and air pollution as well as incidental issues of protests and attacks which often lead to security breaches in oil-producing communities.

Empirics on the nexus of gas flaring and economic growth, particularly in developing economies are not only scant but have produced mixed results. Diugwu et al. (2013) examined the response of the Nigerian economy to gas production, utilization and flaring, from 2001 to 2010, based on Cobb-Douglas non-linear production function, incorporating gross fixed capital and labour as additional predictors of output growth. The study reveals that gas production and flaring retard economic performance. The work of Kareem et al. (2013) which studied gas production, gas flaring and economic growth nexus in Nigeria between 1970 and 2008 within the framework of the neoclassical Cobb-Douglas production function using gross fixed formation and population as proxies for capital and labour also observe that gas flaring adversely affects the performance of the economy. In Itoua et al. (2021), the authors examined the impact of gas production, utilization and flaring on economic growth in the Republic of Congo and observe, among others, no causal link between gas flaring and economic growth, though the OLS result indicates non-significant positive effect of gas flaring on the economy.

In analyzing the health and environmental implications of gas flaring for Nigeria, Ajugwo (2013) observes that the practice has severe negative environmental, economic and health implications, which lead to escalation of poverty in the country and thereby retards output growth. An environmental health risk assessment of pollutants associated with gas flaring in the Niger Delta region of Nigeria between 1965 and 2015 was undertaken by Giwa et al. (2019), and the findings reveal that there are high emissions, measured by the air quality index (AQI), which are hazardous and unhealthy. The work of Adole (2011) presents a strong argument for positive correlation between decline in natural vegetation in the Niger Delta region of Nigeria and gas flaring. Also, Nwanya (2011) shows strong correlation between climate change and some of these emissions. In Okoro et al. (2021), the authors argue that a healthy workforce is essential for enhanced efficiency and productivity of labour, improved capacity utilization of industrial facilities and hence economic growth. The study which used autoregressive distributed lag error correction representation and cointegration techniques to investigate contributory factors behind sustained practice of gas flaring activities in Nigeria from 1970 to 2019, reveals that growth of activities in the real sector induce flaring activities in the country.

2.2.2. Oil rent and economic growth

Chevalier (1975) defines oil rent as the difference between unit price of a measurement of natural resource sold to consumers in the form of refined products and the total average cost of extracting, refining, transporting and distributing the same unit of measurement of the resource. Nigeria ranks among the largest oil producers in the world but without adequate refining capacity to sustain domestic consumption of petroleum products. The country largely exports the oil resource in its primary or crude form and imports refined products, often at a price higher than the export price. This practice triggers cost under-recovery and thereby prompts the use of subsidy to achieve full-cost recovery plus profit for the sector. Payment of subsidy in a country like Nigeria, with manifest cases of corruption, nepotism, weak governance and institutional structures, no doubt, shifts financial resources away from economy as it tends towards rent-seeking practices. The attendant underfunding the real sector could have adverse implications for productivity growth.

In this study, we hypothesize a negative effect of oil rent on economic performance. However, evidence from literature does not show consistency of outcomes. For instance, Satti et al. (2014) used ARDL and VECM method to examine the nexus of natural resource abundance (proxied as natural resource rents) and economic growth in Venezuela from 1971 to 2011. The regression result reveals that abundance of natural resources reduced Venezuela's economic performance during the period. In addition, the VECM Granger causality test shows bi-directional causality between resource abundance and economic growth in both the long- and short-run periods.

Using autoregressive distributed lag (ARDL) approach, Ike et al. (2016) estimated the relationship among oil dependence (proxied as ratio of oil rents to GDP), manufacturing performance and output growth in Nigeria from 1970 to 2011. The authors observe robust positive short-run effect of oil rent on GDP growth. However, long-run estimation reveals strong negative effect of oil rent on the economy and thereby validates the existence of Dutch disease syndrome in the country during the period.

Based on data obtained from a panel of 95 countries over the period 1980–2017, Vespignani et al. (2019) also observe negative relationship between resource-abundance and economic growth, thus further confirming the paradox of poverty in the midst of plenty or resource curse syndrome. They however argue that the economic performance of resource-rich countries can be improved through increased openness which enables them to achieve competitive prices for their products as well as access technologies that enable more efficient production process.

Lucky and Nwosi (2016) deployed the vector error correction model (VECM) and Granger causality tests in investigating the connection between oil production and Nigeria's economic growth between 1981 and 2014. The regression estimates indicate that oil revenue and oil exports did not significantly support the growth of the real economy. The result also shows non-significant negative effect of crude oil production on the economy. In addition, Granger causality estimation shows support for bi-directional or feedback hypothesis of energy-growth nexus. Aimer (2018) conducted a study of 9 oil exporting countries over the period 1997–2015 to ascertain the response of economic activities to oil rent using panel regression and pairwise Dumitrescu Hurlin panel causality test. The observed dependence of the oil exporting countries on oil rent is further reinforced by the regression estimates which show strong positive effect of oil rent on the economy of the selected countries.

Fuinhas et al. (2015) used data obtained from a panel of 21 oil producing nations over the period 1970–2012 to examine the nexus of oil rents and economic growth within a multivariate framework that incorporates oil production to primary energy consumption, crude oil prices, oil consumption per capita, and goods export per capita. Panel estimation based on the dynamic Driscoll-Kraay estimator, with fixed effects, indicates short-run dependence of the economy on oil consumption and oil prices, and long-run dependence on oil production. However, the study also reveals that oil rents depress economic performance in both short- and long-run time horizons. Also, contradicting the advocates of resource curse hypothesis, based on econometric analysis of data from 11 oil-rich countries from the Middle East and North Africa (MENA) for the period 1996 to 2014, Malattah and Malattah (2016) report significant positive effect of oil rent on economic growth. In addition, they also argue that oil rent counters economic diversification policies through rent-seeking activities, and thereby recommend good governance as a veritable tool for positive transformation of the economy through productive engagement of natural resources. Alkhathlan (2013) used autoregressive distributed lag (ARDL) method to estimate the relationship between oil production and economic growth in Saudi Arabia from 1971 to 2010. The result indicates that revenue from crude oil sales accelerates economic growth in the short- and long-run.

Akanni (2007) conducted a panel regression analysis of data obtained from a sample of 60 African and non-African countries (47 oil-exporting and 13 non-oil exporting) over the period 1970–2000. The study provides empirical validation of the resource curse syndrome for oil-rich countries. It reveals that absence of democratic governance and weak institutions promote rent-seeking practices which depress economic growth. The work of Kaznacheev (2013) provides further support for the role of governance and institutions in achieving growth through effective utilization of natural resources. The author argues that natural resource endowment in itself does not constitute a blessing or a curse, but it is rather the quality of institutions that determines the ultimate impact of natural resources on the economy.

Following the outcome of analysis of data from a panel of 31 oil exporting nations from 1992 to 2005, Arezki and Bruckner (2009) show that oil rents promote corruption and deteriorates political rights. The authors investigated the relationship among oil rents, corruption and state stability. Though the study did not provide a direct link between oil rent and output growth, the observed positive impact of oil rent on corruption and its weakening effect on political rights suggest an indirect negative connection between oil rent and economic growth. The work of Sachs and Warner (1995) further reinforces the negative effect of natural resources on output growth in a panel study of 18 countries over the period 1971–89. In the work of Mbingui et al. (2021) which analyzed the nexus of oil rent and economic development in Congo between 1987 and 2016, it was also observed that oil rent depresses economic performance. While affirming the negative effect of oil rent on economic growth, Ramey and Ramey (1995) attribute the negative result to price volatility of natural resources.

2.2.3. Fossil fuel and economic growth

Fossil fuel, particularly petroleum products, and its associated revenue play critical roles in the economic and environmental state of resource-rich nations. While petroleum products constitute essential inputs in the construction and transportation industry, in addition to production of lubricants, solvents, plastics and agro-allied materials needed for industrial development, influx of oil revenue boosts infrastructural development and capital formation, though there is also the prospect of the emergence of Dutch disease syndrome if not productively deployed.

Nigeria is a lower middle income country with high hydrocarbon sales dependence. Nigeria's government has one of the highest oil dependencies for its level of production and Nigeria's inequality is approximately within the middle bracket of the oil exporting nations. Furthermore, there is some indication of inequality increasing with higher levels of oil production. There is strong evidence for oil abundance decreasing levels of poverty (as measured by the poverty headcount ratio) in oil exporting countries. Low levels of oil production are associated with higher levels of poverty and high levels of production are associated with low levels of poverty. Ironically Nigeria presents a glaring exception. Natural resource abundance has not translated to sustained economic growth for Nigeria. Nigeria's real GDP growth rate has averaged 1 percent per annum since 1960 in contrast to Botswana, another resource rich Sub-Saharan African economy, which has enjoyed sustained economic growth of about 7 percent annually over the same period. Nigeria is highly dependent on oil revenues, which comprise about 82 percent of government's total revenues. Since 2004 government expenditure has been linked to a benchmark oil price fiscal rule (OPFR) so as to reduce the effects of a volatile oil price on fiscal expenditure, and the government has continued to rely extensively on oil revenues for its operations.

Just as some oil producing countries have transited to the class of industrial and developed nations while others have become poor, if not poorer, in spite of large scale production and export of the commodity, empirics on the nexus of fossil fuel production and output growth have produced mixed outcomes. Solarin (2020) used FMOLS method to estimate the effect of oil production, capital and labour on economic growth in America between 2002Q1 and 2019Q4 within the framework of Cobb-Douglas production function. The result shows the American economy as strongly dependent on oil for growth. The work of Diugwu et al. (2013) indicates that Nigeria's economic expansion between 2001 and 2010 is significantly linked to its dependence on natural gas. Kareem et al. (2013) reveal that gas production and labour led to improvement in output growth in Nigeria between 1970 and 2008. Using ordinary least squares (OLS) method to estimate the contribution of the oil sector to the Nigerian economy between 1970 and 2005, Odularu (2008) observes that crude oil production greatly contributes to the expansion of economic activities. In a related study, Jahangir and Dural (2018) estimated the nexus of crude oil, natural gas and economic growth in a panel of countries bordering the Caspian Sea region over the period 1997–2015. Countries included in the study are Azerbaijan, Russia, Turkinistan, Iran and Kazakhstan. The panel regression result indicates that crude oil and natural gas significantly promote output growth. With regard to causality, the study shows one-way causal flow from the economy (GDP) to crude petroleum sector and from natural gas to GDP. In contrast, based on data for 1977–2010, Tamba (2017) did not establish causal relationship between crude oil production on economic growth in Cameroon using vector autoregressive (VAR) approach. Using autoregressive distributed lag (ARDL) approach to investigate the relationship between oil production and economic growth in Saudi Arabia during the period 1971–2010, Alkhathlan (2013) observes that domestic consumption of crude petroleum products depresses economic performance over the long and short-term periods.

Table 1
Variables, description, and sources.

Variables	Description	Sources
GDP per capita (constant 2010 US$)	GDP divided by mid-year population	World Bank (2020)
Gross fixed capital formation (% of GDP)	Gross fixed capital formation (formerly gross domestic fixed investment) includes land improvements and fixed assets.	World Bank (2020)
Exports of goods and services (% of GDP)	Exports of goods and services in the economy	World Bank (2020)
Employment in industry (% of total employment) (modelled ILO estimate)	Percentage of the population engaged in industrial employment	World Bank (2020)
Population growth (annual %)	Annual population growth rate	World Bank (2020)
Oil rents (% of GDP)	Oil rents are the difference between the value of crude oil production at world prices and total costs of production.	World Bank (2020)
Gas flare		OPEC (various Years)
Fossil fuel	Fossil fuel comprises coal, oil, petroleum, and natural gas products.	World Bank (2020)
Source: Authors' Compilations		

3. Empirical model and method of analysis

3.1. The data and expectations

This study uses annual data on eight (8) variables. The dependent variable is gross domestic product per capita *(PC)*, while oil rents *(OILR)*, fossil fuel *(FOS)*, gas flaring *(FLARE)* are the main explanatory variables. To analyse these intrinsic interactions, we control for (i) gross fixed capital formation (*GFCF,* proxy for investment) included to capture infrastructural investment in the oil and gas sector; (ii) employment in industry *(EMP)* represents the percentage of productive labour force; (iii), exports *(EXP)* require enormous industrial and manufacturing activities which require the use of energy inputs that invariably contribute to economic growth; and (iv) population growth *(POPGR)*. Details about each variable are indicated in Table 1. The data span is from 1990 to 2019 and all indicators are obtained from the World Development Indicators of the World Bank (2020) except gas flaring sourced from BP Statistical Review of World Energy (2020), and OPEC Annual Statistical Bulletin (2020).

3.2. Pre-estimation checks - unit root tests

To determine the appropriate estimation technique, it becomes necessary to test if the variables exhibit a unit root to avoid spurious results. The graphical depiction (Fig. 1) reveals that all the variables under investigation do not seem to be stationary around its mean and may exhibit a unit root.

In other to prevent spurious regressions, it is expedient to test the series for stationarity. Engaging the augmented Dickey-Fuller (ADF) and the Phillip-Perron (PP) tests, the results shown in Table 2 reveal that the variables exhibit mixed integration as some are stationary at level while some are at the first difference. Most importantly, the dependent variable is stationary at the first difference. Hence, these outcomes support the deployment of the ARDL technique in addressing the objectives of the study.

3.3. The empirical model

Pursuant to the outcome of the stationarity test, this study used the autoregressive distributed lag (ARDL) model framework developed by Pesaran and Shin (1998) and popularized by Kripfganz and Schneider (2016) to investigate whether Nigeria's economy is dependent on oil rents, gas flaring, and fossil fuel. Given the advantages of the ARDL technique which, among others, include its suitability for small and finite samples, ability to derive unbiased long-run estimates of the model's parameters, and applicable regardless of the order of integration of the underlying variables, which can be integration at order zero, one, or mixed but not at two (Okoye et al., 2021; Adeleye, 2020; Adeleye et al., 2020). Thus, following Pesaran and Shin (1998); Pesaran et al. (2001) and Kripfganz and Schneider (2016), we modify the generalised ARDL $(p,\ q,\ \ldots,\ q)$ model as:

$$Y_t = \varphi_{0i} + \sum_{i=1}^{p} \delta_i \mathbf{Y}_{t-i} + \sum_{i=0}^{q} d_i' \mathbf{Z}_{t-i} + \sum_{i=0}^{q} \beta_i' \mathbf{X}_{t-i} + v_t \quad [1]$$

Where: Y_t represents the GDP per capita; $(\mathbf{Z}_t')'$ is a row vector of control variables (*GFCF, EMP, EXP* and *POPGR*); $(\mathbf{X}_t')'$ represents a column vector of the main explanatory variables (*OILR*, *FLARE*, and *FOSSIL*) that are allowed to be purely $I(0)$ or $I(1)$ or co-integrated; δ, d, and β are coefficients; φ is the constant; $p,\ q$ are optimal lag orders; v_t is the white noise error term with unobservable zero mean. To control for outliers, heteroscedasticity and establish elasticity relationships, all the variables with the exception of *POPGR* are transformed into natural logarithm.

To specifically address the study questions, Equation [1] is split into three equations. While maintaining the control variables in all the models, economic growth is expressed as a function of oil rents (equation (2)), gas flaring (equation (3)), and fossil fuel (equation (4)). The three specifications are explicitly expressed as:

$$\ln PC_t = \omega_{0i} + \sum_{i=1}^{p} \delta_i \ln PC_{t-i} + \sum_{i=0}^{q} \eta_i \ln OILR_{t-i} + \sum_{i=0}^{q} \theta_i' \mathbf{Z}_{t-i} + u_t \quad [2]$$

$$\ln PC_t = \omega_{0i} + \sum_{i=1}^{p} \delta_i \ln PC_{t-i} + \sum_{i=0}^{q} \xi_i \ln FLARE_{t-i} + \sum_{i=0}^{q} \theta_i' \mathbf{Z}_{t-i} + s_t \quad [3]$$

$$\ln PC_t = \omega_{0i} + \sum_{i=1}^{p} \delta_i \ln PC_{t-i} + \sum_{i=0}^{q} \lambda_i \ln FOS_{t-i} + \sum_{i=0}^{q} \theta_i' \mathbf{Z}_{t-i} + j_t \quad [4]$$

The three equations were specified separately to show their distinct relationships with economic growth since putting all three variables together in one equation will becloud their respective marginal impact. Where, ln = natural logarithm; , η, ξ, λ and θ are parameters to be estimated; ω is the intercept; u_t, s_t, and j_t are the error terms that are independently and identically distributed (i.i.d). The rest features are as previously defined.

3.4. Error correction model

In the event of the establishment of cointegration relationships, Equations [2] to [4] are estimated using the restricted autoregressive distributed lag (ARDL) error correction representation approach specified in the generalised form as:

$$\Delta \ln PC_t = b_0 + \gamma(b_1 \ln PC_{t-i} - \beta' \mathbf{X}_{t-i} - d' \mathbf{Z}_{t-i}) + \sum_{i=1}^{p-1} a_1 \Delta \ln PC_{t-i} + \sum_{i=0}^{q-1} \omega_{Xi} \Delta \mathbf{X}_{t-i} + \sum_{i=0}^{q-1} \psi_{Zi} \Delta \mathbf{Z}_{t-i} + e_t \quad [5]$$

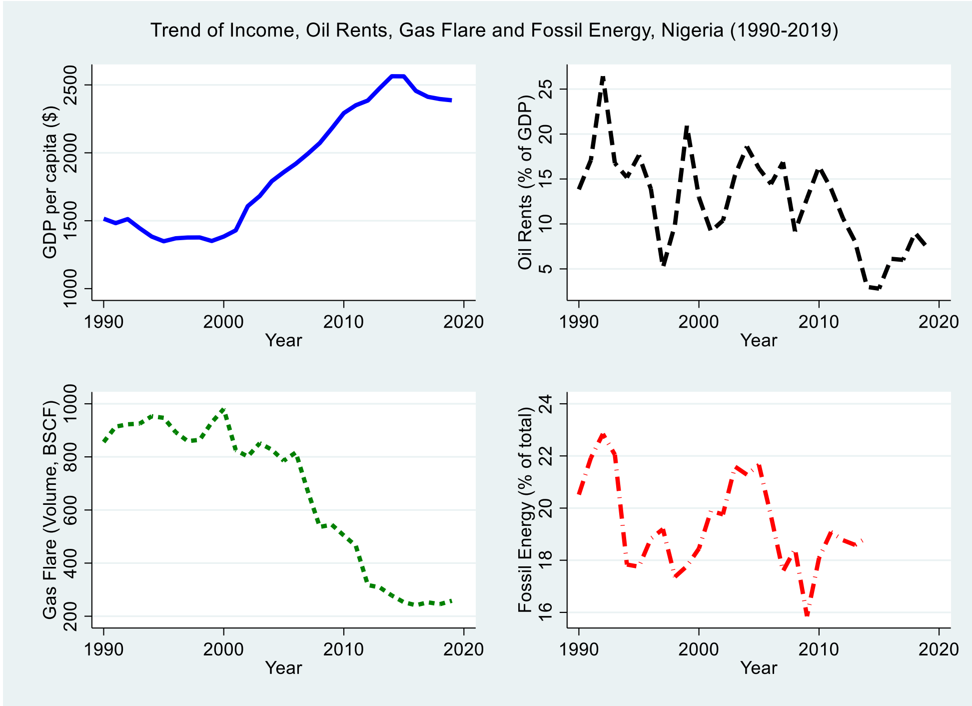

Fig. 1. Graphical plots of the series under consideration. Source: Authors' Computations from World Bank (2020).

Table 2
ADF and PP unit root tests.

Variables	ADF			PP		
	Level	1st Diff.	Decision	Level	1st Diff.	Decision
LnPC	−0.830	−2.685*	*I*(1)	−0.171	−2.636*	*I*(1)
lnGFCF	−1.433	−3.491***	*I*(1)	−1.603	−4.376***	*I*(1)
lnEMP	−2.215	−2.585*	*I*(1)	−1.508	−2.412**	*I*(1)
lnEXP	−2.179	−4.484***	*I*(1)	−2.681*	N/A	*I*(0)
POPGR	−7.108***	N/A	*I*(0)	−0.835	−1.844*	*I*(1)
lnOILR	−2.504	−5.809***	*I*(1)	−2.410	−5.240***	*I*(1)
lnFLARE	0.146	−3.285**	*I*(1)	0.438	−4.505***	*I*(1)
lnFOS	−2.669*	N/A	*I*(0)	−2.422	−4.992***	*I*(1)

Note: ***, **, and * represent statistical significance at the 1%, 5%, and 10% levels, respectively; Estimations augmented with lag structures obtained from Akaike Information Criterion (AIC); ln = Natural logarithm; PC = GDP per capita; OILR = Oil Rents; FLARE = Gas Flaring; FOS = Fossil Energy; GFCF = Gross fixed capital formation; EMP = Employment in Industry; EXP = Exports; POPGR = Population Growth.Source: Authors' Computations.

Where Δ is the difference operator; $\gamma = 1 - \sum_{j=1}^{p} \delta_i$ is the speed of adjustment coefficient; the terms in *( )* represents the error correction term, *ECT*, which is the residual from the long-run equation; a_1, ω, and ψ are the short-run dynamic coefficients of the model's adjustment to long-run equilibrium. Equations [5] states that $\Delta \ln PC$ depends on its lag, the differenced explanatory variables and also on the equilibrium error term. If the latter is positive, then the model does not converge to long-run equilibrium but since γ is expected to be negative, its absolute value decides how quickly equilibrium is restored.

4. Results and discussions

4.1. Summary statistics and pairwise correlation analysis

From Table 3, the basic statistical properties of the variables (see upper panel) reveal that the average per capita GDP is US$1878.72 for the period under review and the standard deviation of 454.06 gives the indication that there is wide disparity of per capita income within the population. The mean values of oil rents, gas flaring and fossil fuel are 12.54, 6760.94 and 19.35, respectively. Similarly, the standard deviations of these variables show that the values of the variables in the dataset are greatly dispersed from their averages. With their respective statistical significance ranging from 1% to 10%, the lower panel of Table 3 reveals the pairwise correlation analysis. All the regressors, with the exception of *POPGR* exhibit negative association with *PC*. By implication, as the regressors increase in magnitude, economic contraction occurs. This is implausible and contradicts a priori expectations except for gas flaring. It is important to state that exploitation of natural resources is known to have two opposite effects. Firstly, it increases the country's income and; secondly, it triggers the process of de-industrialization as new investment decisions become skewed in favour of the natural resource sector. This leads to rent-seeking behaviour with associated corrupt practices that depress economic performance. Hence, further empirical examination and validation of the relationship between each of the main regressors and economic growth is justifiable.

4.2. Bounds cointegration test results

Having established that the variables are integrated of different

Table 3
Summary statistics and pairwise correlations.

Variable	PC	OILR	FLARE	FOS	GFCF	EMP	EXP	POPGR
Observations	30	30	30	25	29	29	29	30
Mean	1878.715	12.539	660.943	19.347	28.231	11.847	22.158	2.576
Std. Deviation	454.06	5.437	274.99	1.751	11.918	0.826	6.361	0.07
Minimum	1348.681	2.803	241.419	15.854	14.169	10.147	9.218	2.489
Maximum	2563.9	26.43	980.658	22.845	53.122	13.041	36.023	2.681
Pairwise Correlations								
lnPC	1.000							
lnOILR	−0.527***	1.000						
lnFLARE	−0.911***	0.698***	1.000					
lnFOS	−0.19	0.252	0.292	1.000				
lnGFCF	−0.940***	0.539***	0.673***	0.327	1.000			
lnEMP	−0.508***	−0.067	0.205	0.417**	0.600***	1.000		
LnEXP	−0.366*	0.449**	0.535***	0.173	0.276	−0.3	1.000	
POPGR	0.899***	−0.342*	−0.604***	−0.23	−0.650***	−0.623***	−0.151	1.000

Note: ***, **, and * represent statistical significance at the 1%, 5%, and 10% levels, respectively; ln = Natural logarithm; PC = GDP per capita; OILR = Oil Rents; FLARE = Gas Flaring; FOS = Fossil Energy; GFCF = GFCF = Gross fixed capital formation; EMP = Employment in Industry; EXP = Exports; POPGR = Population Growth.Source: Authors' Computations.

Table 4
Bounds cointegration test results.

Cointegration hypotheses	*F*-statistics
$F_{lnPC}(lnGFCF_t\|lnEMP_t\|lnEXP_t\|POPGR_t\|lnOILR_t)$	7.101**
$F_{lnPC}(lnGFCF_t\|lnEMP_t\|lnEXP_t\|POPGR_t\|lnFLARE_t)$	10.593***
$F_{lnPC}(lnGFCF_t\|lnEMP_t\|lnEXP_t\|POPGR_t\|lnFOS_t)$	8.282***

Note: *** and ** represent significance at 1% and 5% level, respectively. The critical values for the *F*-statistics from Kripfganz and Schneider (2018) are 4.965, and 7.260 for 5% and 1% significance levels, respectively. Results are Stata-generated using the *"estat ectest"* command.Source: Authors' Computations.

orders, we proceed to analyse if there exists a cointegration among the variables using the ARDL bounds test approach (based on the error correction representation) as developed by Pesaran et al. (2001). The bounds test is mainly based on the joint *F*-statistic whose asymptotic distribution is non-standard under the null hypothesis of no cointegration. The null hypothesis is rejected if the *F*-statistic is higher than the critical value of both the *I*(0) and *I*(1) regressors, and not rejected if otherwise (Pesaran and Shin, 1998; Kripfganz and Schneider, 2016). The results are shown in Table 4.

For the three models, the comparisons indicate that the null hypothesis of no cointegration is rejected at the 5% and 1% level, respectively as there are unique cointegrating relationships among the variables. These results suggest that across all models, *GFCF, EMP, EXP, POPGR, OILR, FLARE,* and *FOS* are the forcing variables that move first when a common stochastic shock hits the system. The implication of the above finding is that: *PC* follows changes in these indicators. The evidence of cointegration, therefore, justifies the examination of long- and short-run dynamics using the error correction representation (ECM) of the ARDL model.

4.3. Error correction model (ECM) results[1]

The combined results for the ECM analysis are displayed in Table 5. Restricting interpretations to the variables of interest, in the long-run oil

Table 5
ARDL-ECM Results (Dependent Variable: lnPC).

Variables	OIL RENT	GAS FLARE	FOSSIL FUEL
	[1]	[2]	[3]
Adjustment Term			
lnPC, lag	−0.5159***	−0.3956***	−0.7772***
	(-3.25)	(-3.53)	(-4.31)
Long-Run Coefficients			
lnGFCF	−0.4949***	−0.8638***	−0.2340***
	(-4.24)	(-3.29)	(-3.64)
lnEMP	1.1367**	0.1962	0.0912
	(2.87)	(0.52)	(0.45)
lnEXP	0.1139	−0.0281	−0.0725**
	(1.22)	(-0.60)	(-2.30)
POPGR	1.9362***	0.7604	2.0412***
	(4.04)	(1.17)	(5.54)
lnOILR	0.0535*		
	(2.00)		
lnFLARE		0.3013*	
		(1.93)	
lnFOS			0.2939***
			(3.29)
Short-Run Coefficients			
ΔlnGFCF	0.1646**	0.2510***	0.1122*
	(2.43)	(4.33)	(2.05)
ΔlnGFCF, lag		0.0941*	
		(1.78)	
ΔlnEMP	−0.9277**		
	(-2.67)		
ΔlnEXP	−0.0439*		
	(-1.77)		
Constant	0.4401	2.3935**	1.6596
	(0.43)	(2.23)	(1.74)
ARDL (p,q, …,q)	(1,1,1,1,0,0)	(1,2,0,0,0,0)	(1,1,0,0,0,0)
No. of Obs.	27	26	23
R-Squared	0.733	0.813	0.773

Note: ***, **, and * represent statistical significance at the 1%, 5%, and 10% levels, respectively; *t*-statistics in *( )*; Δ = Difference Operator; ln = Natural logarithm; PC = GDP per capita; OILR = Oil Rents; FLARE = Gas Flaring; FOS = Fossil Energy; GFCF = GFCF = Gross fixed capital formation; EMP = Employment in Industry; EXP = Exports; POPGR = Population Growth.Source: Authors' Computations.

rents exhibit a positive (0.0535) and statistically significant effect at the 10% level. The coefficient indicates that a percentage change in oil rents leads to 0.054 per cent increase in economic growth. This outcome, though expected, affirms the reality that Nigeria's economy is oil-dependent. In other words, the oil-led-growth hypothesis holds such that shocks to oil revenue exert significant impact on the country's economy. The observed growth-enhancing impact of oil rent confirms

[1] The optimal lag length for the model is 4. Using the Stata routine *"varsoc"*, it is obtained from the choice of Bayesian information criterion (BIC), Hannan–Quinn information criterion (HQIC) and Akaike information criterion (AIC) of which they all gave the same value. However, due to missing values and correlation of the lags, the three models are not robust to using four-period lags. Hence, the OILR and FOS models are estimated with one-period lag while the FLARE model used two-period lags. The exact lag structure as automatically derived from Stata *ardl* routine is indicated in Table 5.

the oil-dependence growth hypothesis reported in Aimer (2018), Malattah and Malattah (2016) and Alkhathlan (2013), but opposes the resource curse argument sustained in Satti et al. (2014), Ike et al. (2016), Vespignani et al. (2019), Fuinhas et al. (2015), Akanni (2017), Lucky and Nwosi (2016), Mbingui (2016), among others. The result of this study therefore did not confirm the resource curse hypothesis for Nigeria.

Also, gas flaring shows a positive (0.3013) and statistically significant effect at the 10% level in the long-run. The coefficient demonstrates that a percentage change in gas flaring activities contributes to 0.30 per cent increase in economic growth, on average, *ceteris paribus*. Not only did this outcome not conform to prior expectations, it also contradicts the findings of Diugwu et al. (2013), Kareem et al. (2013), Ajugwo (2013) which reveal gas flaring as a drain of natural resources and therefore an impediment to growth. We attribute the deviation from a priori to internal dynamics and structural peculiarities of the Nigerian economy. Since oil production induces gas flaring, it suggests that (i) increased revenue associated with high volume of oil production adequately compensates for the expected loss in revenue due to flaring; (ii) the cost of salvaging flared gas may have counted as financial gain to the economy, and (iii) the improved performance of other sectors of the economy may have resulted in significant value-addition to the economy. In addition, since this study covers a particular period, this is valid for the period to which it relates.

Similarly, the coefficient of fossil fuel is positive (0.294) and statistically significant at the 1% level in the long-run. This outcome suggests that a percentage change in the production of fossil fuel will cause economic growth of 0.294 per cent, on average, *ceteris paribus*. This result suggests that the unhindered exploitation of fossil fuel constitutes an accelerator to growth. The observation that fossil fuel production accelerates economic performance further validates the energy-dependency of Nigeria's economy. This result aligns with the findings of Solarin (2020), Diugwu et al. (2013), Kareem et al. (2013), Odularu (2008), Jahangir and Dural (2018), among others, but counters the outcomes of Alkhathlan (2013) and Tamba (2017).

Notably, these variables do not exert any short-run impact on economic growth but contemporaneously with zero lags. Furthermore, across all specifications, the error correction term (denoted *Adjustment*, the first lag of the growth rate) is found to be negative and statistically significant. This term shows the speed of adjustment to restore equilibrium following a deviation from the long-run relationship. A negative and significant error correction term indicates how quickly the model returns to equilibrium. A relatively high adjustment coefficient (in absolute term) indicates a faster adjustment process. From the results, it is observed that for the respective variables of interest (oil rent, gas flare and fossil fuel), about 52 per cent, 40 per cent, and 78 per cent of the previous year's shocks revert back to the long-run equilibrium in the current year. Lastly, the goodness-of-fit of the models indicates R^2 of between 73% and 81% explains the percentage of the variation in economic growth explained by the regressors.

4.4. Robustness checks

For the robustness checks, Table 6 highlights the results from the fully modified ordinary least squares (FMOLS) and the Canonical cointegration techniques. These are cointegration techniques used by related energy studies (Danish, Ulucak and Khan, 2019; Nasira et al., 2019; Nathaniel et al., 2019; Sinha et al., 2019; Hdom and Fuinhas, 2020). Across the different specifications, the signs of OILR and FOS are consistent with those of the main analysis in Table 5 which suggest that a percentage change in oil rents leads to between 0.06 and 0.07 per cent increase in the growth rate while the increase associated with fossil fuel is between 0.28 and 0.26 per cent. Again, the oil rent-economic growth and fossil fuel-economic growth results support the oil-led growth hypothesis and counters the resource curse argument for Nigeria. We find a statistically significant negative coefficient for FLARE which aligns with a priori argument that gas flaring activities are inimical to economic growth. The result indicates that a percentage change in gas flaring 0.19 and 1.06 per cent increase in economic growth.

4.5. Diagnostic Tests Results

The last issue addressed is the goodness of fit of the ARDL-error correction models. For this purpose, series of diagnostic and stability tests were carried out. The diagnostic tests examine serial correlation, heteroscedasticity, conditional heteroscedasticity, Ramsey's RESET test, stability and normality. The results reported in Table 1A (See Appendix) indicate that there are no challenges of misspecification,

Table 6
FMOLS and Canonical Results (Dependent Variable: lnPC).

Variables	*Fully Modified OLS*			*Canonical Regression*		
	[4]	[5]	[6]	[7]	[8]	[9]
lnGFCF	0.0522	0.351***	−0.0959**	0.000470	0.663***	−0.121**
	(0.670)	(11.47)	(-2.310)	(0.00366)	(18.52)	(-2.120)
lnEMP	0.962***	0.920***	0.275***	0.584**	0.624***	0.363**
	(5.389)	(9.831)	(3.183)	(2.243)	(9.911)	(2.361)
lnEXP	−0.0211	−0.136***	−0.0754***	−0.0732	0.0481***	−0.0819***
	(-0.814)	(-13.27)	(-4.752)	(-1.512)	(8.001)	(-3.318)
POPGR	2.638***	5.041***	2.500***	2.323***	2.683***	2.501***
	(8.962)	(39.67)	(16.88)	(7.610)	(57.06)	(9.592)
Trend	0.0168***	−0.00828***	0.00385*	0.0146***	−0.0143***	0.00319
	(5.797)	(-6.181)	(1.928)	(3.707)	(-11.58)	(1.273)
lnOILR	0.0592***			0.0701***		
	(3.758)			(3.594)		
lnFLARE		−0.192***			−1.060***	
		(-9.480)			(-29.24)	
lnFOS			0.281***			0.262***
			(7.163)			(4.775)
Constant	−2.154*	−7.107***	0.0358	−0.0787	3.839***	−0.0169
	(-1.680)	(-10.89)	(0.0573)	(-0.0543)	(11.81)	(-0.0172)
Observations	27	27	23	27	27	23
R-squared	0.961	0.618	0.990	0.983	0.969	0.991
Lag in VAR	1	2	1	1	2	1

Note: ***, **, and * represent statistical significance at the 1%, 5%, and 10% levels, respectively; *z*-statistics in ( ); Δ = Difference Operator; ln = Natural logarithm; PC = GDP per capita; OILR = Oil Rents; FLARE = Gas Flaring; FOS = Fossil Energy; GFCF = GFCF = Gross fixed capital formation; EMP = Employment in Industry; EXP = Exports; POPGR = Population Growth.Source: Authors' Computations.

heteroscedasticity, higher-order autocorrelation, stability (see Fig. 2 in Appendix) or normality in the models. This implies that the results from our analyses are robust and reliable for making inferences.

5. Conclusion and recommendations

The study estimated the influence of gas flaring, oil rent and fossil fuel on Nigeria's economic performance over the period 1990–2019 using autoregressive distributed lag (ARDL-ECM) representation as the main analytical method, while fully modified OLS (FMOLS) and canonical cointegration regression (CR) methods were deployed to check for robustness of the estimates. The study highlights significant positive contribution of oil rent gas flare and fossil fuel to the Nigerian economy during the period. Based on the observed outcome, we sustain the argument for oil-led growth hypothesis in Nigeria and therefore state that, within the scope of our study, the natural resource curse or Dutch disease hypothesis is not validated. Notwithstanding the observation of economic growth in spite of gas flaring, the authors opine the economy can do better if flaring is incrementally reduced until totally eliminated, and therefore recommend that appropriate policies be developed and implemented towards this goal. In particular, critical infrastructures should be developed to aid transformation of associated natural gas to useable energy, especially electricity and liquefied natural gas.

Author statement

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Appendix

Table 1A
Diagnostic Tests Results

Specifications	OIL RENTS	FLARE	FOSSIL	Conclusion
	Stat./*p*-values	Stat./*p*-values	Stat./*p*-values	
Correlogram	0.068/0.794	0.318/0.853	0.297/0.586	No autocorrelation
Breusch-Godfrey (autocorrelation)	1.855/0/173	2.243/0.157	12.331/0.102	No higher-order autocorrelation
Breusch-Pagan (heteroscedasticity)	7.665/0.5682	16.059/0.246	10.908/0.143	No heteroscedasticity
ARCH LM	0.059/0.8074	0.322/0.571	0.275/0.600	No conditional heteroscedasticity
Ramsey RESET (omitted variables)	4.017/0.062	5.621/0.137	2.126/0.165	No omitted variables
Jarque-Bera (normality)	5.791/0/0.055	1.407/0.495	0.828/0.661	Evidence of normality
Cumulative Sum of Residuals	Stable	Stable	Stable	Evidence of stability

Source: Authors' Computations.

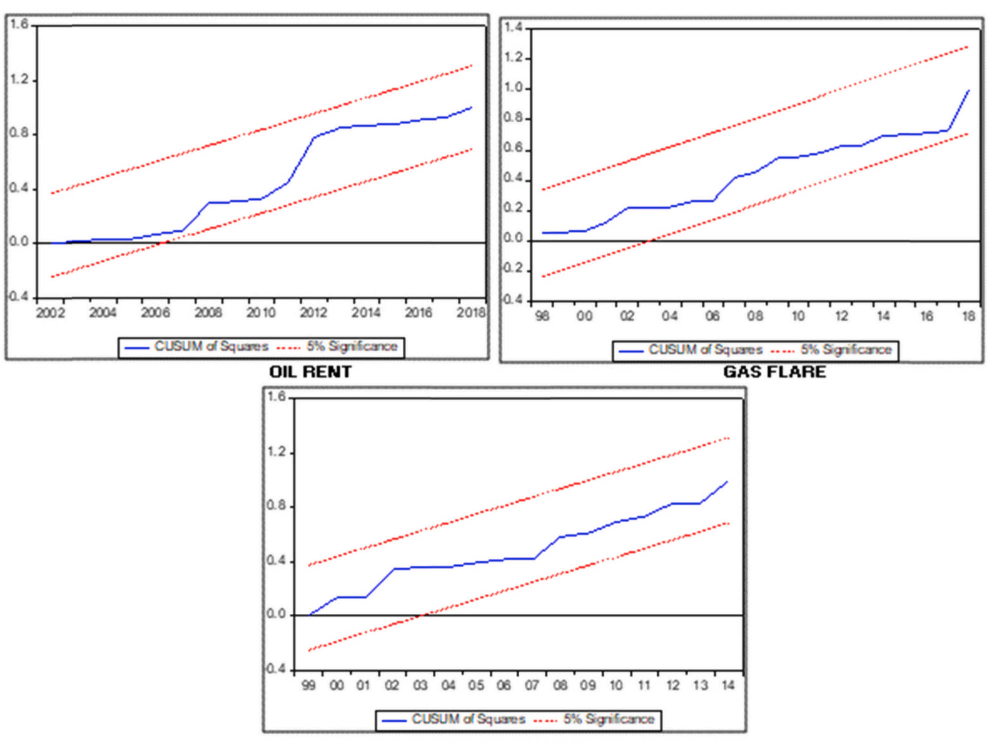

Fig. 2. CUSUMSQ Plot for the 3 Models. Source: Authors' Computations.

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