Acta Univ. Sapientiae, Economics and Business, **9**, (2021) 102–114

DOI 10.2478/auseb-2021-0006

Oil Price and Macroeconomic Fundamentals in African Net Oil-Exporting Countries: Evidence from Toda–Yamamoto and Homogeneous Causality Tests

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Abstract. Despite the wealth of literature on the oil price growth examinations, there is a shortage of research on the causality between oil prices and various macroeconomic fundamentals with regard to the group of net oil-exporting countries in Africa. This study examines the causality between oil price volatility and macroeconomic fundamentals in net oil-exporting countries in Africa using the Toda–Yamamoto and homogeneous causality techniques to gauge the nexus in the selected countries from 1995 to 2019. Our findings from the panel causality test suggest that oil price volatility significantly Granger causes the economic growth of the selected net oil-exporting countries in Africa. However, a mixed outcome was observed for the cross-sectional analyses using the Toda–Yamamoto causality test. Hence, the study offers the need for a policy framework that would drive the output growth as oil price changes continue to threaten macroeconomic variables.

Keywords: oil price volatility, macroeconomic fundamentals, net oil-exporting countries, Toda–Yamamoto causality
JEL Classification: C10, E32, Q43

1. Introduction

The dynamics of crude oil make it an integral part of sustainable development in developed countries, and net oil-exporting countries in Africa are no exception. The stylized fact of the net oil-exporting countries in Africa suggests that energy remains a driving and motivating force on which the economies rely. Predictably, volatilities in oil prices have significant impacts on macroeconomic fundamentals. Oil prices have been confronted with historical crises ranging from political, economic, and other changes since the 1970s, and maintain their volatility to date. In 2020, oil prices decreased significantly as a result of the coronavirus

pandemic lockdown, which indicates another dramatic chapter in the history of oil industry, as most oil investors and stakeholders did not prepare for the recent collapse. While oil prices have shown a modest rebound following the collapse, it is not clear whether most of the net oil-exporting countries' earnings from crude oil sales will be sustainable due to the continued decrease in their budgets. In addition, the prevailing COVID-19 pandemic across the world has dramatically reduced demand for the world's largest oil-consuming economies (International Energy Agency, 2020). It is therefore questionable, mostly in the context of the COVID-19 outcome, that low oil prices will benefit consumers as market forces continue to disrupt demand, which further upset the expansion plans of oil-exporting economies and, most relevantly, provide sufficient funding to healthcare industries to combat COVID-19.

From a theoretical standpoint, the impact of crude oil price volatility on macroeconomic activities could be transmitted through a multitude of channels, including supply side, wealth transfer, real balance, inflation, and sector adjustment effects (Brown and Yücel, 2002). As oil prices continue to rise, output and employment opportunities will be damaged as marginal production cost increases (Brown and Yücel, 2002). Aggregate demand can also be reduced as this price increase results in revenue redistribution between net oil suppliers and exporters. A plethora of empirical examination had focused on how oil price volatility impacts various phases of the macroeconomic factors in both oil-importing and oil-exporting countries (Hamilton, 1983; Ferderer, 1996; Guo and Kliesen, 2005; Hamilton, 1996; Lardic and Mignon, 2006; Cologni and Manera, 2008; Iwayemi and Fowowe, 2011; Farzanegan and Markwardt, 2009; Tang, Wu, and Zhang, 2010; Rafiq, Salim, and Bloch, 2009; Omojolaibi, 2013; Ogede, George, and Adekunle, 2020). These studies provide an outstanding overview of prior studies on this topic which have uncovered that the uncertainty with crude prices is directly linked to the supply chain and that the volatility of crude prices has a considerably significant impact on the economic indicators, such as output, inflation rates, unemployment, interest rates, and exchange rates, which have been identified to be asymmetric.

Also, another set of empirical investigations have argued that the relationship between unanticipated changes in energy prices and macroeconomic fundamentals has weakened over time due to the role of monetary authorities and call for alternative sources of energy (Iwayemi and Fowowe, 2011; Omolade, Ngalawa, and Kutu, 2019; Ogede, et al., 2020). Barsky and Kilian (2004) report a one-way relationship between macroeconomic variables and oil prices. Aliyu (2009) extends the literature on the subjects by exploring both linear and non-linear models for Nigeria. The author employs Wald tests, Granger causality, and VAR methodologies to gauge the nexus and provides evidence that oil price shocks do not Granger cause real GDP at 5 percent significance level. With regard to Nigeria, Babajide

and Soile (2015) report a similar result by exploring quarterly data spanning from 1980:Q1 to 2011:Q4. However, the recent oil prices collapsed amid the COVID-19 pandemic, and the economic slowdown across the globe has renewed debate on oil price-macroeconomic fundamentals. The interdependence between oil prices and macroeconomic indicators is, therefore, one of the debates that need to be discussed at length, considering the usefulness of oil as a key input for the production process and major global export products over years.

Remarkably, a review of macroeconomic activities in Africa's oil-exporting countries reveals that the economies have been linked to the oil sector, suggesting that the region's macroeconomy is exposed to volatilities of crude oil price. As oil prices and COVID-19 continue to threaten the global economies, the four largest net oil exporters in OPEC from Africa, namely Nigeria, Algeria, Angola, and Gabon, have begun to bear the attendant impacts of the volatilities in oil prices. Thus, given the dearth of the literature and the diversity in resources and macroeconomic frameworks of the selected countries with regard to the nexus between volatilities in oil prices and various macroeconomic fundamentals, the current study – in contrast to most existing literature – uses the Toda and Yamamoto (1995) causality technique along the homogenous panel causality test to investigate the nexus. Likewise, the evaluation of volatility models using the realized volatility (RV) model was adopted to gauge oil price volatility as against the erstwhile studies that modelled oil price volatility around the GARCH family models (see Salisu and Fasanya, 2013). Following Ogede (2020), realized volatility (RV) is measured as the sum of the intra-quarter rate of return squares following Andersen and Bollerslev (1998) and generates an unbiased and efficient model of volatility estimates (Chen and Hsu, 2012). This study, therefore, fills the knowledge gaps by using high-frequency data to model oil price volatility using a realized volatility model, while the ingenuity of this study will assist the government and stakeholders with the crucial tools for developing policy frameworks that ease the unfriendly outcomes of oil price volatility on macroeconomic fundamentals in Africa.

The remainder of this study is systematized as follows. Section 2 discusses an overview of the literature, while section 3 focuses on methodology and sources of data. Section 4 summarizes the empirical results, while Section 5 concludes the study.

2. Review of Relevant Literature

There is a vast empirical literature focusing on the examination of the relationship between oil prices and various macroeconomic indicators for diverse nations and periods with diverse methodologies. Among the major empirical standpoints that focused on how oil price volatility significantly impacts macroeconomic indicators,

see: Guo and Kliesen, 2005; Hamilton, 1996; Lardic and Mignon, 2006; Cologni and Manera, 2008; Iwayemi and Fowowe 2011; Farzanegan and Markwardt, 2009; Tang, Wu, and Zhang, 2010; Rafiq, Salim, and Bloch, 2009; Omojolaibi, 2013; Ogede, et al., 2020. However, an appraisal of the literature shows that most of the previous empirical examinations assumed linear specification and largely confirm causality stemming from oil prices to output growth. Hamilton (1996) argued, for example, that the specification for a net increase in oil prices significantly improves the model description of the relationship between oil prices and economic output. A further review of extant studies suggests that the outcomes depend on the directions of causalities (see Barsky and Kilian, 2004; Aliyu, 2009; Korhan, Vahid, and Nigar, 2015). For example, Korhan et al. (2015) examine the causal relationship between oil price and macroeconomic indicators using the data between 1961 and 2012. The study reports a unidirectional relationship from oil price to output growth. In a similar vein, Apere and Ijomah (2013) report a one-way causality between the interest rate, the exchange rate, and the price of crude oil.

Besides, several empirical pieces of literature have modelled volatilities using techniques such as vector autoregressive (VAR), autoregressive distributed model (ARDL), elasticity estimation, generalized autoregressive conditional heteroskedasticity (GARCH), and exponential GARCH models (EGARCH). Narayan and Narayan (2008), for example, employ both GARCH and EGARCH models to model oil price volatilities and contend that the GARCH performs better. In another study, Hooker (1999) employs both the bivariate and multivariate autoregressive (VAR) techniques to examine the long-term stability of the effect of oil prices on GDP and confirms the existence of a direct link between crude oil prices and output. Bercement, Ceylan, and Dogan (2009) examine the effects of oil prices on the growth output of some MENA countries and argue that the oil price increase exerts a direct influence on economic growth, except Israel, Djibouti, Morocco, Egypt, Jordan, Bahrain, and Tunisia. Using the Granger Causality approach, Guo and Kliesen (2005) analysed the impact of oil price uncertainty on the underlying economic activity in the United States and documented the negative effect of volatility crude oil price on economic growth from 1984 to 2004. In addition, the study shows the asymmetrical impact of fluctuations in oil prices on macroeconomic activities. Ghosh and Kanjilal (2014) examined the dynamic effect of oil price shocks on the macroeconomic fundamentals of India from 1991:M3 to 2009:M1 and contended that oil price shocks impact inflation and foreign exchange reserve.

Besides, Awunyo-Vitor, Samanhyia, and Bonney (2018) investigated the causal relationship between oil price variation and the economic growth of Ghana using Johansen cointegration and Granger causality tests in Ghana. The findings indicated a negative correlation between the shifts in oil prices and output growth and, as such, the change in oil prices does not have to influence the expansion of the output growth. Ogede et al. (2020) have recently explored the ARDL panel mean

group model on quarterly data from 1995 to 2018 and reported that the volatility of the oil price is negative and statistically significant with the inflation coefficient in the long-run model of the oil-exporting countries of Africa. The results show that a 1 percent increase in global oil price volatility will lead to a 0.02 percent decrease in inflation in the long term, a proxy of Africa's oil-exporting countries' consumer price index (CPI). From the foregoing discussions, not an iota of the extant studies focused on the group of net oil-exporting countries as the volatilities in oil prices amid COVID-19 continue to threaten the fiscal capacities as well as a policy framework of many African countries.

3. Sources of Data and Methodology

This study explores quarterly data for output growth, oil price, inflation, and interest rate of Nigeria, Angola, Algeria, and Gabon. Oil price data is sourced from the OPEC database, while real gross domestic product growth rate (RGDP_GR), inflation proxy with consumer price index (CPI), and interest rate (IR) were sourced from the World Bank Development Indicators. The data cover 1995Q1 to 2019Q4. All data except realized volatility (RV) are transformed into logarithmic forms to reduce the heteroskedasticity effect. Thus, the goal of this paper is to test for the causal relationship between the oil price volatility, real GDP growth, inflation, and interest rate for the selected African net oil-exporting countries. Toda–Yamamoto's (1995) and Holtz-Eakin et al's (1998) procedure of causality is employed against the conventional Granger causality test. These countries were selected based on the availability of data and their relevance in the global oil market.

Studies such as Shan and Sun (1998) and Zapata and Rambaldi (1997) have provided evidence that Toda–Yamamoto's (1995) and Holtz-Eakin et al's (1998) techniques have similar advantages in magnitude as regards the likelihood probability ratio (LR). The advantage of this approach, as referred to in Zapata and Rambaldi (1997), lies in its ability to perform better when important predictor bias is not excluded, while optimal lag lengths and appropriate sample size were used. It also limits the risk associated with possible consequences of incorrect identification of the order of integration of the series (Kelly and Mavrotas, 2001). The Toda–Yamamoto process of the causality test overcomes the issue of invalid asymptotic critical values when the causality analysis is performed in the case of non-stationary or even cointegrated series. The method uses the modified WALD test to restrict the parameters of the VAR (k) or MWALD procedure (where k is the lag length of the system). This technique has an asymptotic x^2 distribution when a VAR) would be estimated. The significance of the MWALD statistics in the hypotheses indicates the rejection of the null hypothesis of non-Granger causality from Mt differentials to RV and vice versa. The VAR model specified in

this study focuses on using the selected macroeconomic variables to factor the relationship of the economy with oil price shocks; we defined $P_{t,2}$ as a vector of stationary economic variables:

$$P_{2,t} = \Delta RV_t, \Delta(M_t), \tag{1}$$

where ΔRV_t is the first difference of the log of real oil prices and $\Delta(M_t)$ is the first difference of the log of macroeconomic variables. Thus, the reduced form of $P_{2,t}$ can be modelled as:

$$P_{2,t} = \propto + \beta_1 P_{2,t-1} + \cdots + \beta_z P_{2,t-p} + \varepsilon_{2,t}\, \beta(L) P_{2,t} \phi = \alpha + \varepsilon_{2,t} \tag{2}$$

Consequently, the causality between the selected macroeconomic factors (M_t) and oil price volatility (RV_t) based on Toda and Yamamoto (1995) is tested. The RV is gauged following Andersen and Bollerslev (1998); the quarterly RV equation is specified as the sum of squared intra-year returns, which is thus given as:

$$RV_t{}^2 = \sqrt{\sum_{t=1}^{D} (logP_{tj} - logP_{tj-1})^2}, \tag{3}$$

where P_{tj} is the observed quarterly price of the oil at global oil, t and j are the intermediate intra-quarter time intervals. However, the study estimated the following bivariate VAR (k) model:

$$M_t = \propto_1 + \sum_{i=1}^{c+d} \beta_{1i}\, M_{t-1} + \sum_{j=1}^{e+d} \gamma_{1j}\, RV_{t-j} + \varepsilon_{1t} \tag{4}$$

$$RV_t = \propto_2 + \sum_{i=1}^{c+d} \beta_{2i}\, RV_{t-1} + \sum_{j=1}^{e+d} \gamma_{2j}\, M_{t-j} + \varepsilon_{2t}, \tag{4}$$

where d is the maximal order of integration order of the variables in the model, c and e are the optimal lag length of M_t and RV_t, while error terms are denoted by ε_{1t} and ε_{2t}, which is assumed to be white noise with zero mean and no autocorrelation. Arising from equations (4) and (5), there is causality from oil price volatility (RV) to macroeconomic fundamentals (M_t) if null hypothesis: H_0: $\gamma_{11} = \gamma_{12} = \cdots \gamma_{1p} \neq 0$. Similarly, there is causality from macroeconomic fundamentals (M_t) to oil price volatility (RV) if null hypothesis: H_0: $\varphi_{21} = \varphi_{22} = \cdots \varphi_{2p} \neq 0$.

4. Empirical Result and Discussions

The goal of this paper is to test for the causal relationship between the oil price volatility and macroeconomic fundamentals (M_t) for the net oil-exporting countries in Africa. *Table 1* presents the descriptive statistics of the selected variables. These show that the standard deviations are lower compared to the means except for the interest rate (IR). The ranges of the variables are rather large.

Table 1. *Descriptive statistics*

Variables	Mean	Maximum	Minimum	Std. Deviation
CPI	84.480	240.840	1.000	39.463
IR	17.334	160.000	2.000	33.419
RGDP_GR	106.269	265.430	1.000	16.813
lnCPI	4.168	5.484	0.000	1.051
lnIR	2.129	5.075	0.693	0.947
RV	3.738	4.796	2.188	0.700
lnRGDP_GR	4.646	5.581	0.000	0.279
Average Oil Price Volatility				
2-Period Standard Deviation Oil Price Volatility			2.43473325	
Realized Oil Price Volatility			2.176556815	

Source: authors' computation using E-views 10

Table 2 reports the Levin–Lin–Chu, Harris–Tzavalis, Hadri LM, and Im–Pesaran–Shin tests. The model with constant and time trend has been chosen for the analysis, while the null hypothesis of the existence of unit root is estimated and reported for all the variables. The time trend is found to be significant for the variables. Hence, the model with the constant trend was selected to formulate a VAR. The Harris–Tzavalis test could not be conducted for the volatility index in the panel due to serial correlation amongst panels.

Table 2. *Unit root test for panel data*

Unit Root/ Indicators	Levin–Lin–Chu		Harris–Tzavalis		Hadri LM		Im–Pesaran–Shin	
	Level	**1st Diff.**	**Level**	**1st Diff.**	**Level**	**1st Diff.**	**Level**	**1st Diff.**
RV	0.000	0.000	-	-	0.590	0.853	0.000	0.000
lnCPI	0.0758	0.000	0.9428	0.000	0.000	0.0000	0.7641	0.000

Unit Root/ Indicators	Levin–Lin–Chu		Harris–Tzavalis		Hadri LM		Im–Pesaran–Shin	
	Level	**1st Diff.**	**Level**	**1st Diff.**	**Level**	**1st Diff.**	**Level**	**1st Diff.**
lnIR	0.0253	0.000	0.0000	0.000	0.000	0.9803	-	-
lnRGDP_ GR	0.0000	0.000	0.000	0.000	0.000	0.9889	0.0446	0.000

Source: authors' computation using E-views 10

To explore the causal interactions between the selected variables, the study performs a homogenous panel causality test along with the Toda–Yamamoto causality test. The appropriate lag length is selected through the Schwarz criterion (SC) with the specification of a maximum lag of 3, and so are the later empirical tests.

4.1 Granger Causality Test in Homogenous Panel

The result of the Granger causality test in the homogenous panel is presented in *Table 3* following Holtz-Eakin et al. (1988). The dynamic panel homogenous causality test, as reported in *Table 3*, reveals a unidirectional causality initiating from interest rate to consumer price index. An equivalent trend of unidirectional causality is witnessed triggering from interest rate to oil price volatility and from consumer price index to the growth of gross domestic product (GDP). Besides, there is a bidirectional causality from the growth of gross domestic product to interest rate, from oil price volatilities to consumer price index, and gross domestic product growth in the selected net oil-exporting countries in Africa. This finding suggests that the oil price volatility significantly Granger causes the selected net oil-exporting countries in African economic growth. The finding contradicts the works of Aliyu (2009) and Soile and Babajide (2015) with regard to Nigeria.

Table 3. *Homogenous panel causality test*

Null Hypothesis	**Causality**	**Chi-sq.**	**Prob.**
LNCPI ≠>LNIR	lnNIR → lnCPI	78.299	*0.000
LNIR ≠>LNCPI		0.596	0.440
lnRGDP_gr ≠>LNIR	lnRGDP_gr ↔ lnNIR	4.605	**0.032
LNIR ≠>lnRGDP_gr		10.165	*0.001
RV ≠>LNIR	lnNIR → RV	0.814	0.367
LNIR ≠>RV		14.065	*0.000
lnRGDP_GR ≠>LNCPI	lnCPI → lnGDP_gr	0.823	0.364
LNCPI ≠>lnRGDP_gr		178.207	*0.000

Null Hypothesis	Causality	Chi-sq.	Prob.
RV ≠>LNCPI	RV ↔ lnCPI	5.83	*0.016
LNCPI ≠>RV		240.671	*0.000
RV ≠>lnRGDP_ gr	RV ↔ lnGDP_gr	15.136	*0.000
lnRGDP_gr ≠>RV		0.790	*0.037

Source: authors' computation using E-views 10

*Notes: Asterisk(s) *, **, *** represent(s) the rejection of the null hypothesis at 1% and 5% significance levels. The symbol → denotes unidirectional causality, ↔ denotes bidirectional causality, while ≠> implies does not Granger cause.*

4.2 Results of Toda and Yamamoto's Causality Test

As reported in the preceding subsection, the study carried out lag selection criteria to determine the appropriate lag of these variables such that the VAR model implementation requirement will be satisfied. The residual of this model was further diagnosed for the presence of serial correlation to ensure our selected model is adequate. The results, as reported in *Table 4*, show the various Toda–Yamamoto Granger causality test results of each variable in the model by country. The null hypothesis states that there is no causality of the exogenous variable on the dependent variable. *Table 4* showed that for Algeria, there is a bidirectional causality between the real GDP growth rate and interest rate. The unidirectional causality is observed with regard to interest rate to oil price volatility and from real GDP growth rate to oil price volatility. For Angola, there is bidirectional causality from interest rate to the consumer price index. With regard to Gabon, there is unidirectional causality between oil price volatility to real GDP growth rate. For Nigeria, the findings show that no directional nexus was found from various macroeconomic fundamentals and oil price volatility. This is consistent with expectations and the realities of the Nigerian economy as reported by Aliyu (2009).

Table 4. *Result of cross-sectional: Toda and Yamamoto Granger Causality test*

Null Hypothesis	Algeria		Angola		Gabon		Nigeria	
Excluded	**Chi-sq.**	**Prob.**	**Chi-sq.**	**Prob.**	**Chi-sq.**	**Prob.**	**Chi-sq.**	**Prob.**
				Dependent variable: LNCPI				
lnCPI	10.18	0.3357	15.75	*0.0034	7.95	0.1687	6.77	0.1482
lnRGDP_gr	31.11	*0.0003	1.49	0.8276	8.15	0.1481	2.09	0.7176
RV	33.50	*0.0001	1.31	0.8598	4.22	0.5179	0.55	0.9687

Null Hypothesis	Algeria		Angola		Gabon		Nigeria	
Excluded	**Chi-sq.**	**Prob.**	**Chi-sq.**	**Prob.**	**Chi-sq.**	**Prob.**	**Chi-sq.**	**Prob.**
				Dependent variable: LNIR				
lnIR	5.67	0.7719	1.94	0.7462	10.81	0.0552	3.76	0.4393
lnRGDP_ gr	7.71	0.5632	4.825	0.3068	8.52	0.1297	4.56	0.3349
RV	10.26	0.3293	4.99	0.2873	1.96	0.8541	8.44	0.0768
				Dependent variable: LNGDP_GR				
lnIR	28.65	*0.0007	0.82	0.9362	2.17	0.8245	9.95	0.0413
lnCPI	11.85	0.2219	4.47	0.3464	3.75	0.5859	2.19	0.6997
RV	19.85	**0.0189	2.52	0.641	7.46	0.1884	4.24	0.3739
				Dependent variable: RV				
lnIR	5.04	0.8312	1.83	0.7667	1.96043	0.8546	0.39	0.9831
lnCPI	4.74	0.8563	5.86	0.2095	5.12	0.4016	3.43	0.4882
lnRGDP_ gr	7.33	0.6027	2.36	0.6697	26.16*	0.0001	3.82	0.4314

Source: authors' computation using E-views 10

*Notes: Asterisk(s) * and ** represent(s) the rejection of the null hypothesis at 1% and 5% significance levels.*

5. Conclusions and Policy Implications

This study employs the Toda–Yamamoto and homogeneous panel causality techniques to gauge the nexus using time series of realized volatilities of oil prices, GDP growth, consumer price index, and interest rates from 1995 to 2019. The finding from the panel causality test suggests that the oil price volatility significantly Granger causes economic growth in the selected net oil-exporting countries in Africa. The finding contradicts the works of Aliyu (2009) and Soile and Babajide (2015) with regard to Nigeria. However, a mixed outcome was observed for the cross-sectional analyses using the Toda–Yamamoto causality test. The findings show bidirectional causality between the real GDP growth rate and interest rate. The unidirectional causality is observed with regard to interest rate to oil price volatility and from real GDP growth rate to oil price volatility. For Angola, there is bidirectional causality from interest to consumer price index, while there is unidirectional causality between oil price volatility and the real GDP growth rate in Gabon. For Nigeria, the findings show that no directional nexus was found from various macroeconomic fundamentals and oil price volatility. This is consistent with expectations and the realities of the Nigerian economy as reported by Aliyu (2009) and Awunyo-Vitor et al. (2018).

Hence, the weak regulatory regime of the oil industry, coupled with insufficient fiscal policies, further exposes selected African countries to both internal and external shocks, thus having a significant impact on macroeconomic factors, according to our findings. Fiscal policy in these countries faces challenges in the longer term, in terms of intergenerational wealth and fiscal sustainability as well as in the short term, in terms of macroeconomic stability and fiscal planning. While different models are suitable for different economies, the study suggests that more weight is given to the fiscal and monetary structures in the selected countries. As a result, a strong fiscal policy is required to sustain macroeconomic stability and robust growth both during and after the oil revenue boom. Stakeholders must also provide systemic responses to fiscal challenges by creating sound judgment about oil prices in the budget as well as establishing oil stabilization and savings funds. Moreover, market price responses to oil prices may be due to government intervention and public policy frameworks that focus on providing subsidies for fuel, food, and basic services. These policies not only determine the degree to which prices can be adjusted (especially in the short term) but also encourage consumers to buy more than they would have if such measures did not exist. As a consequence, market distortions and inefficiencies are the results of these policies. As a result, these countries must take drastic measures to overhaul their various support schemes to minimize inefficiencies and production costs. To minimize overdependence on the oil sector, the selected countries will also diversify their economies by reshaping other sectors such as agriculture and manufacturing.

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