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Fossil Fuel Energy Consumption, Inflation and Economic Growth in Selected African Oil Producing Countries

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Abstract
The importance of oil in production has been the reason for continuous increase in fossil fuel energy consumption, which further had implications on inflation and economic growth. This study investigated the impact of fossil fuel energy consumption on inflation and economic growth in the African oil producing countries which include Nigeria, Libya, Angola, and Algeria where data was sourced from the World Bank for the period 2011 to 2021. The generalized method of moment (GMM) was applied, and it was found that fossil fuel energy consumption had significant positive impact on inflation; it was also found from the analysis of GMM that fossil fuel energy consumption had significant positive impact on economic growth in African oil producing countries. The study recommended diversification of the economy by encouraging and increasing local manufacturing, and sponsoring more research on developing renewable energy since fossil fuel energy is not renewable and is exhaustible.

Keywords: Energy Consumption, Economic Growth, Fossil Fuel, Inflation
JEL Classification Codes: Q30, Q40, Q50, Q30

1. Introduction

The discovery of oil across African countries and the relationship between fossil fuel energy consumption with inflation and economic growth has posed lots of concerns specifically in the African oil producing countries. The leading oil producing countries in Africa include Nigeria, Libya, Algeria, and Angola among others where in recent times from 2020 to 2023, Nigeria's oil production capacity averaged 1.493 million bpd while the oil production capacity of Libya, Algeria, and Angola averaged 1.16 million bpd, 1.14 million, and 1.07 million respectively (Organization of Petroleum Exporting Countries [OPEC], 2023]. Global economic projections in the African oil producing countries are often based on the

endowed available oil resources where oil constitute the major source of foreign exchange and the major source of national income in these countries. Hence, the fossil fuel energy consumption has a key role in inflationary movements and the performance of economy.

Most of the African oil producing countries have moribund refineries largely attributed to poor leadership where the extracted oil is exported in its crude form, and the refined products are imported at higher prices giving rise to issues of inflations and challenges to economic growth given that the African oil producing countries are heavily import dependent on both consumer and capital goods. The revenue generated from the exports of crude oil in these African oil producing countries is again expended on the importation of refined oil where in most cases, the cost of importing the refined products exceeds the revenues from oil (Goshit & Terese, 2020). In spite of the endowed oil resources, the economies of these African oil producing countries continue to struggle in terms of higher inflationary rates as well as fluctuations in economic growth among other macroeconomic variables.

Empirical studies of Gagliardone and Gertler, (2023); Sangyup, Davide, Prakash, Saurabh, and Marcos, (2017); Chikako and Jaewoo, (2022); Sani, Ismaila, Danlami, Sani, and Yusuf, (2020) supported evidence that rise or fall in oil prices generated inflation in oil resource-rich countries. Inflation rate in Nigeria rose from 21.34% in 2022 to 21.82% in January 2023 (National Bureau of Statistics, 2023), Algeria's inflation drops from 9.27% in 2022 to 8.06% in January 2023 (World Bank, 2023), inflation in Libya increased from 2.8% in 2021 to 4.6% in 2022 (Central Bank of Libya, 2023), while the Angola inflation drops from 21.36% in 2022 to 11.69% in 2023. The economic growth rates in Nigeria, Libya, Algeria, and Angola continue to fluctuate amidst persistent volatilities in global oil price (World Bank, 2023).

The pervasive volatility in fossil fuel prices, the primary energy source in Africa, significantly contributes to consumer price instability. This volatility manifests in the continuous escalation of gasoline pump prices and household utility costs, consequently giving rise to inflation and consequential impacts on economic growth. This study is positioned against the backdrop of recognizing the pivotal role of oil resources in African oil-producing nations, particularly Nigeria, Libya, Algeria, and Angola. The implications of oil's centrality on inflation and economic growth in these selected African oil-producing countries prompted an in-depth investigation into the influence of fossil fuel energy consumption. The study seeks to discern the dynamics between fossil fuel usage, inflationary pressures, and economic growth in this specific geopolitical context. By doing so, it aims

to offer clear insights into the complex relationship between energy consumption patterns, inflationary trends, and overall economic performance, thereby contributing to a deeper understanding of the impacts of fossil fuel dependence in the examined nations.

The specific objectives of the study include to; determine the relationship between fossil fuel energy consumption and inflation in the selected African oil producing countries; and investigate the impact of fossil fuel energy consumption on economic growth in selected African oil producing countries.

2. Review of Related Literature

2.1 Conceptual Literature

2.1.1 Concept of Fossil Fuel Energy

Fossil fuels constitute a category of energy sources derived from ancient plants and organisms that originated during the Carboniferous period. These resources, namely coal, oil, and natural gas, are classified as non-renewable due to the prolonged timeframe-spanning millions of years-required for their formation. Fossil fuels currently stand as the predominant global energy supply, contributing to 82% of the total (Traheka & Tri, 2018). Coal, a prominent fossil fuel type, results from the compression and heating of ancient ferns, plants, and trees. The pressure and heat exerted during this process lead to the hardening of organic matter, forming coal. Oil, another significant fossil fuel, is generated from smaller organisms such as zooplankton and algae. The intricate decomposition of these organic materials into oil occurs under intense pressure. Natural gas, similar to oil in formation, undergoes a lengthier process with higher levels of heat and pressure, causing further decomposition. The utilization of fossil fuel energy extends to various applications, encompassing the power of machines essential for industrialization. This spans from the generation of electricity to serving as a crucial component of transport fuels. The pervasive use of fossil fuels underscores their central role in meeting global energy demands and driving essential processes across industries.

2.1.2 Concept of Inflation

Inflation simply refers to the persistent rise in the general prices of goods and services. It is one of the key macroeconomic variables that is often watched and checked by different economies (Caceres, Poplawski, & Tartari, 2012). Demand pressures especially without adequate monetary policies are expected to trigger inflation, for example, with rising fossil fuel energy prices, most economies become vulnerable to issues of inflation ranging from consumer price index to personal consumer expenditures.

2.1.3 Concept of Economic Growth

Economic growth is used to describe the increase and expansion in the production of goods and services in an economy. It refers to the general increase in the economic activities, and the Gross Domestic Product (GDP) is often used to measure the economic growth. The nominal GDP measures output in the current prices while real GDP takes constant prices adjusted for inflation (Goshit & Terese, 2020).

2.2 Theoretical Review

This study reviewed the augmentation of production and growth theory, building upon neoclassical growth theories as outlined by Stern (2004). Departing from the conventional perspective that regards capital, labor, and land as primary factors of production with fuels and raw materials classified as intermediate inputs, this study introduces a paradigm shift by acknowledging energy, specifically fossil fuels, as a fundamental factor in production and growth.

The rationale behind incorporating energy, particularly fossil fuels, into the factors of production lies in the principles of thermodynamics. The efficiency law of thermodynamics stipulates that a minimum quantity of energy is indispensable for the transformation of matter. Since all production involves some form of matter transformation or movement, energy emerges as an essential factor in the process. This departure from traditional economic perspectives challenges the norm and aligns with the recognition of energy's pivotal role in production and growth.

The adoption of this augmented theory of production and growth justifies the inclusion of the variable of fossil fuel energy consumption in the study. This inclusion is significant for understanding its implications on key economic variables, such as inflation and economic growth. The price and level of fossil fuel energy consumption become critical determinants influencing the cost of goods and services, thereby shaping the overall performance of the economy. Consequently, the adoption of this expanded theory provides a comprehensive framework for analyzing the multifaceted impact of fossil fuel energy consumption on various economic indicators.

2.3 Empirical Literature

Several empirical studies have been conducted to elucidate the relationship among fossil fuel energy consumption, inflation, and economic growth across various economies, employing diverse methodologies. The findings of these studies have often been characterized by a mix of results, occasionally yielding conflicting conclusions.

For instance, an examination of fossil fuel energy consumption and economic growth in Kenya by Otim, Watundu, Mutenyo, and Bagire (2022), employing a Granger-based causality test, revealed a unidirectional causality running from fossil fuel energy consumption to economic growth. The study recommended conservation and policy efficiencies that would encourage the safe usage of fossil fuels for sustainable economic growth in African countries.

In contrast to these works, an exploration of Europe and Central Africa by Zoli (2009) and Caceres, Poplawski, and Tartari (2012) employed the Vector Autoregression (VAR) method. Their focus on emerging markets within the region aimed to analyze the impact of commodity price shocks on inflation. The results highlighted the significance of relative prices to the EU-15 in explaining inflation responses to commodity price shocks in emerging European countries. Notably, in Central Africa, price controls assumed a considerable role, underscoring the influence of region-specific factors on domestic inflation responses to global oil price shocks in developing nations.

Additionally, Choi, Furceri, Loungani, Mishra, and Poplawski (2017) conducted a study assessing the impact of global oil price volatility on domestic inflation. Utilizing a structural VAR with an unbalanced panel of 72 developing and developed countries, their findings revealed that a 10% increase in global oil inflation, on average, corresponded to an approximate 0.4 percentage point rise in domestic headline inflation. This underscores the substantial influence of oil price changes on the intricate dynamics of inflation within both developing and developed economies, emphasizing the global interconnectedness of economic phenomena.

Furthermore, a recent structural VAR analysis conducted by Luca and Mark (2023) uncovered a pass-through effect of oil price shocks to domestic consumer prices in New York. Similarly, an examination of the impact of oil price shocks on inflation in Nigeria, utilizing a non-linear autoregressive distributed lag, indicated that oil price increases led to an upswing in headline, core, and food measures of inflation. Intriguingly, negative oil price shocks resulted in higher inflation in Nigeria when the exchange rate was excluded from the models.

In the context of Africa's oil-exporting countries, a comprehensive study by Sina, Emmanuel, and Ibrahim (2020) utilized the pool mean group estimation procedure aimed to explore the inflationary effect of oil price volatility. The findings suggested that oil price volatility exerted a negative and significant impact on inflation in African oil-exporting countries. Collectively, these diverse studies contribute to a nuanced understanding of the intricate dynamics linking fossil fuel energy consumption, inflation, and

economic growth, revealing the varied impacts across different regions and contexts.

Also, Sani, Ismaila, Abdullahi, Sani, and Yusuf (2020) examined oil price shocks and inflation in Nigeria using Non-Linear Autoregressive Distributed Lag (NARDL). Their finding revealed that increase in oil prices increased the general prices of goods that measure inflation in Nigeria.

3. Methodology

The research employed panel data from 2011 to 2022, focusing on the indices of fossil fuel energy consumption, inflation, and gross domestic product. The selection of this study period was guided by the accessibility of data regarding the variables of interest within the selected African oil-producing nations. All data pertaining to these variables were sourced from the World Bank.

3.1 Model Specification

The methodology adopted for this study followed the Generalized Method of Moments (GMM), a robust estimation technique widely employed in econometrics, particularly for panel data analysis. The GMM stands out as an effective approach for formulating econometric models, allowing for their specification without imposing unnecessary assumptions, as elucidated by Bernadhita, Dian, Mustofa, and Faiz (2014). The GMM estimator is derived by minimizing the criterion function, ensuring that the sample moments align with their population counterparts. In this study, panel data was utilized, representing a comprehensive amalgamation of time series and cross-sectional data. This dataset encompassed observations on numerous individuals or families, each tracked across multiple time points. This approach enables a clear exploration of the dynamic interactions among the variables under investigation.

The panel data sets on a set of countries is specified as follows:

$$y_{it} = x_{it}^{'}\beta + z_{i}^{'}\alpha + \varepsilon_{it} \quad - \quad - \quad - \quad - \quad 1$$

Where y_{it} is dependent variable at time *t*, $x_{it}^{'}$ represent set of explanatory variables at time *t*, β is the parameter to be estimated, while $z_{i}^{'}\alpha$ is called individual effect where $z_{i}^{'}$ is with a constant term α and a set of individual or group of specific variables.

Panel data analysis, often produces over determined systems where there are more moment equations than number of parameters, which informed increasing degree of freedom and anticipation of heteroscedaticity problem (Gujarati, 2004). Thus, Hansen (1982) introduced GMM to solve

the anticipated issues by minimizing criterion weighted function. Thus, the starting point as presented by Hansen (2007) is specified as:

$$Ef(x_t, \beta_0) = 0 \quad - \quad - \quad - \quad - \quad -2$$

Where f has r coordinates and β_0 is an unknown vector in a parameter space. For easy identification in equation (2), it is assumed that $\beta = \beta_0$. Since parameter β_0 is typically not sufficient to write down a likelihood function, other parameters of interest are added to equation (2) to fully specify the probability model that underlies the data generation for the study.

In line with the choice of variables for this study, the functional form of the model for this study is specified as follows:

$$INFL = f(FFEC, ENU, MANE) \quad - \quad - \quad -3$$

$$GDP = f(FFEC, ENU, MANE, INFL) \quad - \quad -4$$

From equation (3) and (4), f is the notation for the functional relationship, *INFL* is inflation, *FFEC* is fossil fuel energy consumption, *ENU* is energy use, *MANE* is manufactures exports, and *GDP* is gross domestic product, a measure of economic growth.

The stochastic form of equation (3) and (4) in line with the GMM specification of likelihood function is identified and specified in equation (5) and (6).

$$INFL_t = \beta_0 + INFL_{t-1} + \beta_1 FFEC_t + \beta_2 ENU_t + \beta_3 MANE_t + \vartheta_t + \lambda_i + \eta_{it} \quad 5$$

$$GDP_t = \beta_0 + GDP_{t-1} + \beta_1 FFEC_t + \beta_2 ENU_t + \beta_3 MANE_t + \beta_4 INFL_t + \vartheta_t + \lambda_i + \eta_{it} \quad 6$$

Where the β's are the parameters to be estimated while ϑ represent the country specific effect; λ is the time specific effect; and ɳ is the two-way stochastic error term.

4. Results and Discussion

4.1 Panel Unit Root Test Result

The panel unit root test results of Im-Pesaran Shim and Levin, Lin and Chu were estimated and presented in Table 1 of this study.

Table 1: Result of the Panel Unit Root Test

Test	Variable	At Level		At First Difference		
		Statistics	Probability	Statistics	Probability	Integration
Levin, Lin & Chu t*	GDP	-3.14580	0.0008	-4.86175	0.0000	I(0)
	INFL	-7.68752	0.0000	-5.23175	0.0000	I(0)
	FFEC	-4.28781	0.0000	-7.19712	0.0000	I(0)

	ENU	-5.72977	0.0000	-8.44472	0.0000	I(0)
	MANE	0.02782	0.5111	-3.23105	0.0006	I(0)
Im, Pesaran and Shin W-stat	GDP	-5.40943	0.0000	-7.30480	0.0000	I(0)
	INFL	-5.27854	0.0000	-5.80984	0.0000	I(0)
	FFEC	-5.22090	0.0000	-6.75044	0.0000	I(0)
	ENU	-3.89161	0.0000	-7.74628	0.0000	I(0)
	MANE	-0.61049	0.2708	-5.49149	0.0000	I(1)

Source: Authors' computations using Eviews 10.0

The result in Table 1 indicated that all the variables were stationary at levels at the order of integration I(0) in both Levin, Lin, & Chu t* and Im, Pesaran and Shin unit root test outcomes except for variable MANE where the Levin, Lin, & Chu t* which assumes common unit root process was stationary at level while the Im, Pesaran, and Shin which assumes individual unit root process was not stationary at levels but became stationary at first difference at I(1) order of integration. The combination of the order of integration as revealed from the outcome of the panel unit root tests in this study favoured the use of GMM which allow for the application of stationary and non-stationary instrumental variables (Kitamura & Phillips, 1997). Hence, it is expected that the estimations in this study would not be spurious or misleading, given the stationarity properties of the variables at different levels.

4.2 Analysis of the GMM Results

The results of the GMM in line with the set objectives of the study were estimated and presented in Table 2 and 3 for objectives one and two respectively. The objective one which sought to determine the impact of fossil fuel energy consumption on inflation in selected African oil producing countries was estimated on the basis of the specifications in equation 5 and presented in Table 2.

Table 2: GMM Result Analysis on Fossil Fuel Energy Consumption and Inflation

Dependent Variable = $INFL_t$		
Number of Instrument = 15		
Number of Observations = 40		
Variable	Estimated Coefficient	Probability Value
$INFL_{t-1}$	3.805974	0.051
FFEC	0.4760011	0.043

ENU	0.4169639	0.030
MANE	-16.14999	0.033
Diagnostic Tests:		
Arellano-Bond test for AR(1)	z = 2.11	0.035
Arellano-Bond test for AR(2)	z = 0.42	0.676
Sargan Test	$Chi^2 = 20.63$	0.024
Hansen Test	$Chi^2 = 0.000$	1.000

Source: Authors' computations from Stata 17

From Table 2, the empirical result of the GMM indicated that the coefficient of the lagged dependent variable $INFL_{t-1}$ was statistically significant at 5% level of significance given the probability value of 0.051, which confirmed that the specified GMM model for this study was dynamic. The Arellano-Bond test for AR(1) was statistically significant (0.035) as required for a system dynamic GMM while the Arellano-Bond test for AR(2) was not significant (0.676) at 5% level of significance which implied that the null hypothesis for the absence of autocorrelation in the stochastic error term was accepted, which further implied that there was no problem of autocorrelation. The Hansen test null hypothesis for over identification restriction not rejected since it was not statistically significant at 5% level and the number of instrument (15) were less than the number of observations (40) as required.

The estimated coefficient of FFEC was positive (0.4760) and statistically significant at 5% level with the probability value of 0.043, which revealed that fossil fuel energy consumption had significant positive relationship with inflation in the selected African oil producing countries. The coefficients of ENU and MANE were 0.4169 and -16.1499 respectively and both statistically significant at 5% significance level which means that energy use had significant positive impact on inflation while manufacturing exports had significant negative impact on inflation in the oil producing countries in Africa.

In order to investigate the impact of fossil fuel energy consumption on economic growth in selected African oil producing countries, the study estimated two-step system dynamic GMM as specified in equation (6) and presented in Table 3.

Table 3: GMM Result Analysis on Fossil Fuel Energy Consumption and Economic Growth

Dependent Variable = GDP_t
Number of Instrument = 18
Number of Observations = 40

Variable	Estimated Coefficient	Probability Value
GDP_{t-1}	1.937254	0.008
FFEC	39.35271	0.029
ENU	21.73925	0.001
MANE	-0.271934	0.049
INFL	42.81037	0.003
Diagnostic Tests:		
Arellano-Bond test for AR(1)	z = 7.26	0.011
Arellano-Bond test for AR(2)	z = 1.39	0.193
Sargan Test	$Chi^2 = 13.31$	0.016
Hansen Test	$Chi^2 = 2.564$	0.724

Source: Authors' computations from Stata 17

The result in Table 3 showed that the number of instruments (18) were less than the number of observations (40) as required for a system dynamic GMM. The AR(2) probability value of 0.193 indicated that the study could not reject the null hypothesis of no autocorrelation which revealed that the specifications were free from the problems of autocorrelation. The null hypothesis for over identification restriction was not rejected since the Hansen Chi^2 value was not statistically significant at 5% significance level given the probability value of 0.724.

From the estimated coefficients of the variables of interest in Table 3, FFEC was positive (39.3527) and significant (0.029) at 5% level of significance, which implied that fossil fuel energy consumption had significant positive impact on the economic growth of African oil producing countries. The estimated coefficients of ENU, MANE, and INFL were 21.7392, -0.2719, and 42.8103 respectively with the corresponding probability values of 0.001, 0.049, and 0.003 respectively, which implied that energy use and inflation had significant positive impact on economic growth in the African oil producing countries while manufacturing exports had significant negative impact on economic growth in African oil producing countries.

4.3 Discussion of Findings

The study found from the empirical analysis of fossil fuel energy consumption and inflation that fossil fuel energy consumption had significant positive relationship with inflation in the African oil producing countries which include Nigeria, Libya, Angola, and Algeria; this finding is in line with (Choi *et al.*, 2017; Sani *et al*., 2020). The positive relationship between fossil fuel energy consumption and inflation suggest that increase

in fossil fuel energy consumption in African oil producing countries implied increase in the cost of production given the volatility nature of global oil prices, the increase in the cost of production induced cost push inflation in Nigeria, Libya, Angola, and Algeria since they are over dependent on oil as the main source of foreign exchange. Hence, changes in the prices of fossil fuel energy whether positive or negative still push up inflation since oil is the major source of national income among the African oil producing countries.

It was also found from the empirical analysis of fossil fuel energy consumption and economic growth that fossil fuel energy consumption had significant positive impact on economic growth in the African oil producing countries. The positive impact of fossil fuel energy consumption on economic growth is attributed to the fact that increased in energy consumption implied increased in production activities that positively contributed to economic growth. It is firms at both large and small scale levels that engage in production of goods and services, which require large amounts of fossil fuel energy consumption. Thus, it is expected that with the increase in consumption of fossil fuel energy, it would expand production leading to increase in economic growth, which means that African oil producing countries leveraged on the availability of the fossil fuel energy resource to achieve growth.

5. Conclusion and Recommendations

Following the close examination of the empirical findings in this study, wherein outcomes were ascribed to the heightened reliance of Nigeria, Libya, Angola, and Algeria on oil as their primary foreign exchange source, robust conclusions have been drawn. The study incontrovertibly establishes a strong and positive relationship between fossil fuel energy consumption and inflation within the African oil-producing countries under scrutiny. Delving into the broader implications of these findings, the study unequivocally concludes that fossil fuel energy consumption exerts a strong and positive impact on economic growth in the selected African oil-producing nations. This explains the pivotal role of fossil fuel dynamics, particularly in the context of economic indicators, emphasizing their tangible influence on the overarching economic development within Africa. The findings not only reinforce the significance of addressing overdependence on oil but also highlight the relationship between energy consumption, economic performance, and inflation dynamics in these nations. Based on the findings, the study recommended the following:

i. In order for the African oil producing countries to overcome the problems accompanied with persistent fluctuations in global oil prices which

often translate into increased domestic prices, the oil producing countries should diversify their economies through manufacturing. With the available raw materials, the African oil producing countries can achieve boosting the manufacturing sector by collaborating with the African Development Bank to finance and encourage local manufactures.

ii. Based on the finding that fossil fuel energy consumption improved economic growth through increased production activities, African oil producing countries should endeavour to prepare for renewable energy since fossil fuel is exhaustible; hence overdependence becomes dangerous. This can be achieved through funding of research in the area of renewable energy in these selected African oil producing countries.

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