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Non-Renewable Energy and Macroeconomic Efficiency of Seven Major Oil Producing Economies in Africa

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Abstract: *This study adopted two-stage DEA to estimate the technical efficiency scores and assess the impact of the two most important components of fossil fuel associated with oil production on macroeconomic efficiency of Seven oil producing African countries during 2005-2012. Our results showed that increasing the consumption of natural gas would improve technical efficiency. Furthermore, increasing the share of fossil fuel in total energy consumption has negative effect on the efficiency of the economies of the top African oil producers. Also, we found that increasing the consumption of primary energy improves efficiency in these economies. We therefore, recommend that governments and other stakeholders in the energy industry should adopt inclusive strategies that will promote the use of natural gas in the short term. However, in the long-run, efforts should be geared towards increasing the use of primary energy, thereby reducing the percentage share of fossil fuel in total energy consumption.*

Keywords: Non-Renewable Energy; Data Envelopment Analysis; Technical Efficiency; Africa.

JEL Classification: Q, Q4, Q43

Introduction

Globally, in the quest for sustainable economic growth, energy resources consumption has been identified as a critical input to achieve this objective. This realisation by most government (at all level) and the wave of urbanization and industrialisation that greeted many economies of the world resulted in the increase in the level of energy consumption and the subsequent oil price shock of the 1970s. Since then, most economies have continued to increase their efforts

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in making better use of energy resources. Reduced investments in energy infrastructure, lower fossil fuel dependency, increased competitiveness, and improved consumer welfare are among the benefits of efficient energy use (Makridou, Andriosopoulos and Zopounidis, 2014).

The global economy is still highly dependent on fossil fuels such as oil, gas and coal which are one of the main causes of carbon (CO_2) emissions. To reduce this emission, the Kyoto Protocol of 1997 was signed as a giant step toward the reduction of greenhouse gases and the promotion of renewable energy intensity among the industrialised countries. In fact, as noted by Halkos and Tzeremes (2013), the European Commission issued the renewable energy directive setting targets for the European Union country-members and wishing that 20% of total energy and 10% of transport energy to come from renewable energy source by 2020 while every country member has set individual goals towards the fiscal year of 2020.

Interesting, among African oil producing countries; the consumption of petroleum products and natural gas (major products of their resource) has increased over the past few decades, with the industrialised countries remaining their largest export markets. Given the high dependence of most of these oil-rich African countries on foreign earnings from crude oil export, the dwindling prospects of oil in the world market tend to make investment in renewable energy an arduous task. Consequently, these economies have the tendency of further increasing domestic petroleum and natural gas consumption, in spite of the attending CO_2 emissions, relative to other alternative sources of energy. This paper is best interpreted as extending the work of Chen and Hu, (2006) to Seven (7) of the top ten (10) oil producing economies in Africa. The increase in energy consumption, especially fossil fuel, among these selected African countries is a source of concern and necessitated empirical studies. This is very important for developing countries, especially in Africa; as more energy use is core to productivity improvement and sustainable economic development. Thus, the pertinent question that easily comes to mind is "does the increase usage in non-renewable energy improve energy efficiency among these selected countries?"

Following the introductory section, the rest of this paper is organized into six sections as follows: the next section, section two provides stylized facts on different energy consumption in Africa. Section three and four illustrate with relevant literature review and theoretical framework and methodology for the study, respectively. While, section five entails the empirical results and discussions of findings, the last section, section six, focuses on the conclusion and policy implications of the study.

Brief Stylised Facts on Different Energy Consumption in Africa

Premised on data obtained from WDI, 2015 and EIA[1], Table 1 revealed the 4-year averages and overall averages of variables of interest between 2005 and 2012. For all the years, Gabon has the lowest labour force among the selected countries, as such; it has the highest per capita GDP and capital stock for all the years which is a reflection of their very low population. In contrast, Nigeria, with the highest amount of labour force, has the lowest per capita GDP and labour force. For all the countries, the 4-year averages of per capital GDP and labour, as well as labour force, increased between the periods 2005-2008 and 2009-2012.

Petroleum and natural gas consumption was highest in Egypt for all the period considered. For instance, Egypt has a 4-year average of petroleum consumption of 1,193.57 thousand barrels per day during 2005-2008, 1,717.85 thousand barrels per day during 2009-2012 and an overall average of about 1,455.71 thousand barrels per day. This is greater than the combined petroleum consumption of other countries (excluding Nigeria) for the period 2005-2008 (as well as for the overall average) and greater than the consumption of all the countries for 2009-2012 period. In terms of the consumption of natural gas, Egypt and South Africa are the leading consumer with an average greater than the combined consumption of the rest of the countries in any period. Egypt recorded 4-year averages of 692.27 billion Cubic feet during 2005-2008 and 713.18 billion Cubic feet during 2009-2012 respectively while South Africa has 4-year averages of 561.47 billion Cubic feet during 2005-2008 and 595.72 billion Cubic feet during 2009-2012 respectively.

However, total energy use per capita is highest in South Africa, followed by Gabon and Algeria while Congo Republic ranked least. In all the countries, except Nigeria, petroleum and total energy consumption increased between 2005-2008 and 2009-2012 period. Similarly, all the countries increased their consumption of natural gas over the two periods Algeria has the highest percentage share of fossil fuel in total energy which remains above 90% between 2005 and 2012 as shown in Figure 1. However, as with Algeria, the percentage share of fossil fuel in total energy has been rising, with slight breaks, since 2005 in Angola, Congo the Republic, Gabon and Egypt. Nigeria has the lowest percentage share of fossil fuel in total energy which fell from about its highest value of 21% in 2005 to its lowest value of about15% in 2009 while South Africa has been reducing its share of fossil fuel since 2008 with a slight increase in 2012. The consumption of primary energy has followed similar pattern with the share of fossil fuel in total energy in all the countries (Figure 2). While primary energy consumption continued to rise for other countries, it was inconsistent in Nigeria and South Africa.

Table 1: Trends of GDP, Capital Stock and Labour Components of Energy Consumption among Seven Oil Producing Countries in Africa

Trends of GDP, capital stock and labour[2]									
	GDP			**Capital Stock**			**Labour**		
Country/Year	2005-2008	2009-2012	Overall Average	2005-2008	2009-2012	Overall Average	2005-2008	2009-2012	Overall Average
Algeria	3067.67	3155.41	3111.54	751.59	1034.33	892.96	10726895.25	11779736.25	11253315.75
Angola	2163.43	2596.97	2380.20	432.77	677.33	555.05	6325078.50	7238594.50	6781836.50
Congo Republic	1729.45	1895.73	1812.59	387.55	526.69	457.12	1497265.00	1697924.00	1597594.50
Egypt	1350.32	1540.04	1445.18	282.26	313.92	298.09	23786834.50	26278654.00	25032744.25
Gabon	6296.44	6353.45	6324.94	1438.27	1691.44	1564.86	516973.75	582631.00	549802.38
Nigeria	861.31	997.67	929.49	74.24	110.74	92.49	45136640.50	50475803.50	47806222.00
South Africa	5494.57	5748.81	5621.69	1031.63	1137.17	1084.40	18397934.75	18674622.00	18536278.38
Trends of energy components[3]									
	Petroleum Consumption			**Natural Gas**			**Total Energy Use**		
Country/Year	2005-2008	2009-2012	Overall Average	2005-2008	2009-2012	Overall Average	2005-2008	2009-2012	Overall Average
Algeria	915.51	1130.96	1023.24	271.81	351.51	311.66	1013.09	1101.89	1057.49
Angola	25.07	25.92	25.50	63.00	107.91	85.45	596.58	675.15	635.86
Congo Republic	8.92	33.28	21.10	8.70	13.28	10.99	317.21	373.66	345.44
Egypt	1193.57	1717.85	1455.71	692.27	713.18	702.72	923.86	952.86	938.36
Gabon	3.18	2.83	3.00	15.09	18.69	16.89	1257.49	1264.54	1261.02
Nigeria	389.83	240.06	314.94	272.83	280.85	276.84	744.22	716.38	730.30
South Africa	127.93	148.47	138.20	561.47	595.72	578.60	2770.49	2786.85	2778.67

Source: Authors' compilation, underlying data from WDI, 2015 and Energy Information Administration (EIA) database

The pattern of dry natural gas consumption is not similar among the selected countries. For instance, while it rose steadily for Algeria, Congo the Republic and Egypt, it fell and rose again for Angola, Gabon, Nigeria and South Africa (see Table 1 above). In terms of petroleum consumption, consumption increased overtime for all the countries, except Congo Republic that has experienced decline since 2010. With the exception of Nigeria, total energy consumption in 2012 was higher than that of 2006 for all the countries with maximum points occurring at different years for various countries. However, this trend does not show any prospect of persistent rise in total energy consumption in the future judging from the unstable trend of the consumption of the various energy components in the high energy consuming economies.

Egypt was the leading consumer of both natural gas and petroleum among the selected countries for all the years with Gabon and Congo Republic being the least consumer of natural gas and petroleum respectively. South Africa remained the highest consumer of primary energy and total energy among the top oil producers in Africa.

Figure 1: Percentage Share of Fossil Fuel in Total Energy

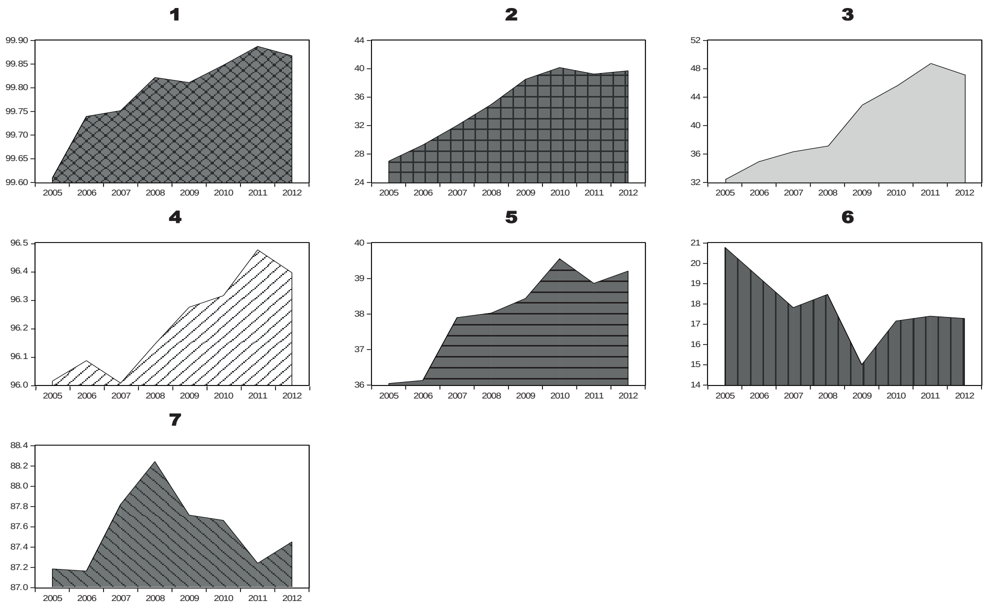
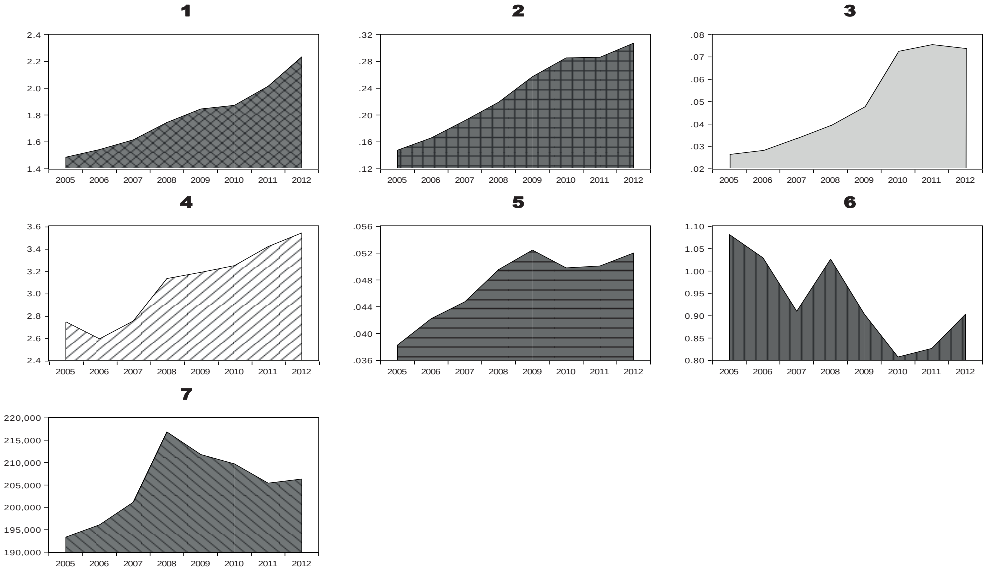


Figure 2: Total Primary Energy Consumption



Source: Computed, underlying data from Energy Information Administration and World Development Indicator.[4]

Furthermore, on the trend, Table 1 shows the average natural gas consumption (ANGC), Average total Petroleum consumption and their growth rates. Average consumption of natural gas (ANGC) was lowest (353.05 billion Cubic feet) in 2006 and highest (526.22 billion Cubic feet) in 2012 with negative growth rates of -2.34% and -2.16% in 2006 and 2010 respectively.

Table 2: Average Natural Gas Consumption (ANGC), Average total Petroleum consumption (ATPC) and their Growth rates

	ANGC	ATPC	GANGC	GATPC
2005	361.50	261.76	-	-
2006	353.05	265.00	-2.34	1.24
2007	367.57	268.38	4.11	1.27
2008	440.18	282.09	19.75	5.11
2009	443.26	282.20	0.70	0.04
2010	433.69	295.75	-2.16	4.80
2011	482.20	300.28	11.18	1.53
2012	526.22	310.98	9.13	3.56

Source: Authors computation; underlying data from Energy Information Administration (EIA) Database.

Meanwhile, average total petroleum consumption (ATPC) grew steadily from about 261.76 thousand barrels per day to about 310.98 thousand barrels per day, hence recording positive growth rates for all the years being considered with the highest growth rate of 5.11% in 2008 (See Table 2).

Literature review

The literature is bias toward developed countries in the examination of macroeconomic efficiency of energy resources. Although, some related studies have attempted to provide empirical evidence for macroeconomic efficiency of energy resources in particular. These studies differ across areas, periods, methodological approaches and findings. Most recent studies reviewed are presented in Table 3 below. In terms of spread, macroeconomic efficiency of energy resources related studies have been at the Cross-country level (Halkos and Tzeremes, 2013; Mohamad and Sald, 2011; Meidani, Falahi and Hosseini, 2013; Simsek, 2014; and Meng, et al., 2014 among others. Country specific study includes, China (Sheng-yun and Zhan-xin, 2011), industrial level Boyd and Pang, 2000. At income groups' level studies such as Simsek, (2014) and Chien and Hu, 2007 are found in the literature.

Specifically, Chien and Hu, (2007) in their study analyses the effects of renewable energy on the technical efficiency of 45 economies during the 2001–2002 through DEA. Results showed that an increase in the use of renewable energy improves an economy's technical efficiency. Chien and Hu, (2007) further compared results between OECD and non-OECD economies; and finds that OECD economies have higher technical efficiency and a higher share of geothermal, solar, tide, and wind fuels in renewable energy that Non-OECD countries. Boyd and Pang, (2000) focuses on the linkage between energy efficiency and productivity, using plant level data. Their results showed evidence for productivity differences between plants as statistically significant in explaining differences in plant energy intensity.

Pertinent to the above, Halkos and Tzeremes, (2013) further examined the relationship between renewable energy consumption and economic efficiency of 25 European countries in 2010. While employing conditional Data Envelopment Analysis (DEA) estimators alongside with non-parametric regressions; results revealed that renewable energy consumption has a positive effect on countries' economic efficiency for lower consumption levels while for higher levels the analysis reveals mixed effects, which are also subject to regional disparities. They therefore, suggested that energy consumption on countries' economic efficiency depends also on countries' specific regional characteristics as well as on the environmental policies adopted (see Table 3 below).

Table 3: Summary of Literature Review

S/N 1.	Author & Year	Country (s) & scope	Methodology		Findings
			Variables	Estimation methods	
1.	Meng, et al., (2014)	16 APEC (1996-2011)	ECC, NG, CO, HY, L, K, Y, CO_2	Two stage DEA window analysis	Energy congestion in 16 APEC countries is mainly from the fossil energy
2.	Christina and George, (2010)	31 countries of Europe in 2004	CO, ECC, NG, HY, Y & CO_2	DEA method for simultaneous analysis of the interrelationships among GDP	Each country can achieve better TE when its increased economic activity is combined with improved ecological performance
3.	Simsek, (2014)	23 OECD countries (1995-2009)	L, K, ECC, Y, NE, CO, & HP	DEA	Determining the reasons of these inefficiencies is important for these countries.
4.	Sheng-yun and Zhan-xin, (2011)	China (1990-2007)	ECC, Y, EC, CO & NG	The generalized out-oriented DEA	China uses less NG and uses more solids and EC
5.	Meidani, Falahi and Hosseini, (2013)	24 oil exporting and importing countries (2002-2008)	L, K, Y & ECC	DEA & dynamic panel data (GMM) approach	Result suggests that industry sector of oil importing countries have advanced technology, high scale and capacity that help them take benefits of oil products consumption without decrease in efficiency.
6.	Mohamad and Sald, (2011)	54 members countries of OIC (2003-2007)	GCE, Y, X, INF & L	3 version of DEA	Three fuel-exporting countries and four least-developed countries top the performance list with Iran and Yemen at the bottom.
7.	Chien and Hu, (2007)	25 countries from OECD and Non-OECD economies between 2001 and 2002	L, K ECC, GT and Y	DEA	Compared to non-OECD economies, OECD economies have higher TE and higher share of GE, solar, tide, and wind fuels in renewable energy.
8.	Boyd and Pang, (2000)	2 major industry sub-segments of container glass and flat glass	EC, Fossil fuel, NG prices, L, K, Y and Cap U	DEA and regression analysis	Productivity differences between plants are statistically significant in explaining differences in Plant energy intensity.
9.	Halkos and Tzeremes, (2013)	25 European countries for the year 2010	ECC, L, K, Y solar, wind, GT and biofuels	Conditional DEA and non-parametric regressions	ECC has a positive effect on countries' economic efficiency for lower consumption levels while for higher levels the analysis reveals mixed effects that are subject to regional disparities.
10.	Hang, et al., (2015)	209 Chinese cities (2008)	L, K, ECC, Y, SO_2	Non-radial directional distance function	Energy inefficiency is negatively correlated with economic development in these cities. According to them, the technology gap of energy inefficiency in middle income cities is significantly smaller than cities with different incomes

Source: Compiled by the Authors; Note: Gross Domestic Product = Y; Hydro-Power = HP; Energy Consumption of crude oil or energy use = ECC; Hydro-electric Energy = HY; Industrial development = ID; Nuclear energy = NE; Natural gas = NG; Capacity Utilisation = Cap U; Coal consumption = CO; Technical Efficiency = TE; = APEC; Electricity Consumption = EC; Organization of the Islamic Cooperation = OIC; Government Consumption Expenditure = GCE; Geothermal = GT; L = Labour force, K = Capital; Export = X; Inflation = INF; SO_2 = fossil fuel consumption emission

Recently, Hang, Sun, Wang, Zhao and Wang, (2015) constructs an energy inefficiency index and discusses sources of energy inefficiency, by simultaneously considering the heterogeneity of production technology, non-radial slacks, and undesirable outputs across 209 Chinese cities. They observed that energy inefficiency is negatively correlated with economic development in these cities. According to them, the technology gap of energy inefficiency in middle income cities is significantly smaller than cities with different incomes.

In terms of estimation techniques; studies have also adopted different techniques alongside DEA. Related studies under review showed different techniques (column 4 in Table 3 above). Such techniques used by previous authors include the Dynamic panel model of generalized method of moment (GMM) (Meidani, et al., 2013), parametric and non-parametric regression (Halkos and Tzeremes, 2013; Boyd and Pang, 2000). Interestingly, studies have also employed different DEA estimations ranging from the two stage DEA window analysis to three version of DEA. In this present study, given that analysis was done for each country in the sample, two stage DEA window analyses and stepwise regression approach was adopted.

Theoretical Framework and Methodology

The estimated model used was the two-stage analysis of DEA. In the first stage, input-oriented data envelopment analysis (DEA) is used to construct an efficiency frontier and generate technical efficiency scores for each of the seven economies in each year; from 2005 to 2012 with the assumption of constant returns to scale (CRS)[5]. The second stage highlighted the stepwise regression analysis of the model; this was done in order to determine the impact of energy consumption on macroeconomic efficiency of seven major oil producing economies in Africa.

Therefore, following the DEA procedures, the CRS model used in this study assumes the optimal mix of inputs and outputs as independent of the country's scale of operation. Each decision making unit (DMU), represented by each country in this case, will seeks to minimize the usage of their inputs given a fixed level of output from such country; since it is in control of the inputs used. Therefore, the objective function for the CRS model used in this study is specified in equation 1 as follows:

$$\text{Maximise } \theta_q = \frac{\sum_{r=1}^{m} UrYrq}{\sum_{i=1}^{n} ViXiq} \quad (1)$$

$$\text{Subject to } \frac{\sum_{r=1}^{m} UrYrj}{\sum_{i=1}^{n} ViXij} \leq 1 \quad (2)$$

Note; $U_r, V_i \geq 0$ for all r and i

Where

Y_{rq} = Vector of outputs for the qth DMU
X_{iq} = Vector of inputs for the qth DMU
U_r = Vector of output weights
V_i = Vector of input weights
θ_q is a scalar and represents the efficiency score of the qth DMU.

There are *n* numbers of inputs. Thus, there exists *n* x 1 vector of input weights. Likewise, there are *m* numbers of outputs and *m* x 1 vector of output weights. Also, there are *k* numbers of DMUs (excluding the focal DMU).

Equations 1 and 2 can be re-expressed as;

$$\text{Maximise } \theta_q = \sum_{r=1}^{m} UrYrq \tag{3}$$

$$\text{Subject to } \sum_{r=1}^{m} UrYrj \leq \sum_{i=1}^{n} ViXij \tag{4}$$

This constant returns to scale (CRS) DEA model implies that the increase in the output is directly proportional to the increase in the inputs implying that the optimal mix of inputs and outputs is independent on the firm's scale of operation. The objective function specified in (3) involves finding values for *U* and *V*, so that the efficiency of the qth DMU is maximized, subject to the constraint that all efficiency measures must be less than or equal to 1. The model is transformed in such a way as to make maximization of the numerator possible by setting the denominator for the unit being evaluated equal to 1. Thus, an additional constraint is introduced and the above non-linear model is transformed into the following linear model;

$$\text{Maximise } \theta_q = \sum_{r=1}^{m} UrYrq \tag{5}$$

$$\text{Subject to } \sum_{r=1}^{m} UrYrj - \sum_{i=1}^{n} VrXrj \leq 0 \quad j = 1, \ldots, k \tag{6}$$

$$\sum_{i=1}^{n} VrXiq \qquad Ur,\ Vi \geq 0 \tag{7}$$

For the second stage analysis, this study uses stepwise regression, as against hierarchical regression, employed by Chien and Hu (2006), which considers explanatory variables according to some specified order. The stepwise procedure defines an a posterior order giving the relative uniqueness of the variables selected. Three models are specified to explain the technical efficiency (TE) of among these countries;

Model 1: $TE = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_5 X_5$ (8)

Model 2: $TE = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_5 X_5 + \beta_6 X_6.$ (9)

Model 3: $TE = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_5 X_5 + \beta_7 X_7..$ (10)

Where X_1 represents capital stock per capita (CAPP); X_2, labour force (LAB); X_3, GDP per capita (GDPC); X_4, fossil fuel as a percentage of total energy (FOSFUEL); $\beta_5 X_5$, primary energy consumption (PRINERCON); $\beta_6 X_6$, natural gas consumption (NATGAS); $\beta_7 X_7$, petroleum consumption. Model 1 estimates the effect of the controlling variables on technical efficiency while model 2 and model 3 introduces natural gas and petroleum in turn as the most important oil products of the top African oil producers.

Data on dry natural gas consumption (Billion Cubic Feet), total petroleum consumption (Thousand Barrels Per Day) and total primary energy consumption (Quadrillion Btu) are collected from renewables and non-renewables information published by International Energy Agency (IEA). Data on total labour force, energy consumption (kg of oil equivalent per capita), gross fixed capital formation (constant 2005 US$), GDP per capita (constant 2005 US$) and Fossil fuel energy consumption (% of total) are collected from the World Development Indicators (WDI) database (World Bank, 2015). Population figures, also sourced from WDI, are used to divide gross fixed capital formation in order to express it in per capita terms.

Empirical Results

Table 4 below showed the descriptive statistics and correlation analysis for the input and output variables. Each variable has 56 observations with mean and median per capita energy consumption across the countries been 1,106.73kg and 947.24kg respectively; the standard deviation of 744.28kg was observed. Capital stock per capita across the seven countries examined stood at an average value of $US603.96, with a median value worth $US450.41 and standard deviation of $US507.95 while, GDP per capita has a mean of $US2,165,709, median of $US2,817.90 and standard deviation of $US8,337,114. Moreover, the average labour force for the selected countries is 15.9 (in millions of persons) with median and standard deviation of 11.2 million and 15.6 million respectively. Correlation analysis reveals that capital stock has negative relationship with labour force and GDP. Also, correlation among the variables is either moderate or weak with capital stock having negative correlation with labour force and per capita GDP.

Table 4: Descriptive statistics and correlation analysis for input and output

Descriptive statistics				
	ENER	CAPP	LAB	GDPC
Mean	1106.734	603.963013	15,936,828	2,165,709
Median	947.2369	450.411092	11,211,937	2,817.902
Maximum	2961.354	1739.99208	52,642,336	52,642,336
Minimum	305.6536	6.10E-06	493,999	804.1524
Std. Dev.	744.2787	507.953015	15,564,598	8,337,114
Observations	56	56	56	56
Correlation analysis				
	ENER	CAPP	LAB	GDPC
ENER	1			
CAPP	0.453	1		
LAB	0.049813	-0.4917173	1	
GDPC	0.008378	-0.3138523	0.301866	1

Source: Author's computation

Data Envelopment Analysis Results

Table 5 shows the technical efficiency scores for each of the seven countries, as well as the country and overall average, from 2005 to 2012. The number of countries that were fully efficient hovered between four and five from 2005 to 2010 but dropped to three in 2011. By 2012, all the selected countries were on the efficiency frontier.

Table 5: Technical Efficiency Scores for Selected top African Oil Producing Economies

Countries	2005	2006	2007	2008	2009	2010	2011	2012	Country Average	Rank[6]
Algeria	0.72482	0.83054	0.77972	0.82114	0.69092	0.68770	0.74824	1.00000	0.78539	7th
Angola	1.00000	1.00000	1.00000	0.79500	1.00000	0.95637	0.95409	1.00000	0.96318	5th
Congo Republic	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	0.94231	1.00000	0.99279	3rd
Egypt	0.48709	0.82084	0.77752	0.79886	0.91323	0.87419	0.83133	1.00000	0.81288	6th
Gabon	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1st
Nigeria	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1st
South Africa	0.73994	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	0.96749	4th
Overall Average	0.85026	0.95020	0.93675	0.91643	0.94345	0.93118	0.92514	1.00000		

Source: Author's Estimation

The overall average technical efficiency revealed that the countries recorded their lowest average of about 85% in 2005 before they remained above 90% between 2006 and 2011 and were fully technically efficient in 2012. These findings are consistent with those of Meidani et al. (2013) who investigated the relationship between major oil products consumption and efficiency of industry sector in selected oil exporting and importing countries. Their results showed slight improvement in the mean economic efficiency of oil exporting countries from 0.987 in 2002 to 0.998 in 2008 while that of oil importing countries moved from 0.981 in 2002 to 1.0 in 2008. This suggests improvement in the process of turning national resources into output over the years giving increasing access to information and improvement in the techniques of production.

On the individual country level, only Nigeria and Gabon remained on the efficiency frontier for all the years while Algeria (the lowest country average of about 79%) and Egypt (country average of about 81%) never operated on the frontier for any of the years.

Second Stage Analysis

The stepwise regression results are shown in Table 6. In model 1, GDP per capita, labour force and capital stock are used as controlling variables with energy input broken down into primary energy consumption and fossil fuel (as a percentage of total energy). GDP per capital and capital stock are negative and significant at 10% and 5% respectively while labour force is positive and significant at 10%. The effect of primary energy consumption on macroeconomic consumption is positive and significant while that of fossil fuel is negative and significant. The R-square for model 1 shows that about 57% of the variation in macroeconomic efficiency is explained by the model. Model 2 introduces natural gas consumption. Within that model 2, Labour force and fossil fuel are negative and significant at 1% while a significantly positive relationship exists between primary energy consumption and macroeconomic efficiency. GDP per capita and capita stock are insignificant. Natural gas consumption is positive and significant at 1% and its inclusion in the model improves the explanatory power of the model to about 65%. These results suggest that increasing natural gas consumption is important and enhances macroeconomic efficiency of African oil producing countries (see Table 6, column 2).

Petroleum consumption is introduced in Model 3 in the place of natural consumption. GDP per capita and capital stock remain insignificant but primary energy consumption and fossil fuel remains significant at 1% while labour force is positive and significant at 10%. Petroleum consumption is insignificant and its inclusion in the model does not significantly improve the explanatory power of the model from 57% as recorded by model 1. Thus, while rising petroleum consumption might slightly boost macroeconomic efficiency of oil rich African countries, it is not necessarily an important ingredient in achieving macroeconomic efficiency goal.

Table 6: Stepwise Regression results for the three models

	MODEL 1	MODEL 2	MODEL 3
C	1.1099 (0.0337)*	1.2380 (0.0507)*	1.1269 (0.0419)*
GDPC	$-1.50x10^{-9}$ ($8.26x10^{-10}$)***	$2.01x10^{-9}$ ($1.26x10^{-9}$)	$-1.64x10^{-5}$ ($2.70x10^{-5}$)
LAB	$2.29x10^{-9}$ ($1.37x10^{-9}$)***	$-4.41x10^{-9}$ ($1.19x10^{-9}$)*	$2.31x10^{-9}$ ($1.38x10^{-9}$)***
CAPP	$-2.01x10^{-5}$ ($2.64x10^{-5}$)**	$-1.19x10^{-5}$ ($2.44x10^{-5}$)	$-2.28x10^{-9}$ ($1.39x10^{-9}$)
PRINERCON	$7.27x10^{-7}$ ($1.69x10^{-7}$)*	$1.61x10^{-6}$ ($3.19x10^{-7}$)*	$6.63x10^{-7}$ ($1.93x10^{-7}$)*
FOSFUEL	-0.0028 (0004)*	-0.0062 (0.0011)*	-0.00345 (0.0008)*
NATGAS		0.0002 ($6.27x10^{-5}$)*	
PETCON			$8.94x10^{-5}$ (0.0001)
R-squared	0.5737	0.6471	0.5778
Adjusted R-squared	0.5311	0.6039	0.5262
F-statistic	13.4591	14.9769	11.1787
Prob(F-statistic)	$2.53x10^{-8}$	$1.22x10^{-9}$	$7.96x10^{-8}$
Durbin-Watson stat	1.8140	1.7775	1.8803

Source: Author's computation

For the three models, primary energy consumption is consistently positive and significant while fossil fuel as a percentage of total energy consumption is consistently negative and significant. The implication of this is that an increase in the consumption of natural gas and total primary energy while reducing the share of fossil fuel in total energy will improve macroeconomic efficiency. This result is consistent with Chien and Hu (2006) who found that increasing the input of traditional energy decreases technical efficiency. However, this present study maintains that increasing natural gas consumption, which as a component of fossil fuel will enhance efficiency but it must be complemented with a rising total primary energy use which ultimately, reduces the percentage share of fossil fuel in total energy consumption.

Conclusion and Policy Implications

We adopted the DEA method to estimate the technical efficiency scores for the 7 economies from 2005 to 2012. Moreover, we employed the stepwise regression analysis to assess the impact of the two most important components of fossil fuel associated with oil production - petroleum and natural gas - on macroeconomic efficiency.

Increasing the consumption of natural gas will significantly improve technical efficiency. On the other hand, increasing the input of petroleum consumption does not have any significant effect on macroeconomic efficiency. Furthermore, increasing the share of fossil fuel in total energy consumption has negative effect on the efficiency of the economies of the top African oil producers. The reason for this could be the inherent carbon emissions associated with fossil fuel consumption which has been on the increase over the years with its attendant negative effect on economic activities. Also, we found that increasing the consumption of primary energy improves efficiency in these economies. Thus, the findings of this paper then support the on-going campaign for clean energy as a way to improve efficiency in these oil-rich African economies. Having confirmed that increasing the use of natural gas can significantly improve an economy's technical efficiency, we therefore, suggest that governments and other stakeholders in the energy industry should adopt inclusive strategies that will promote the use of natural gas especially in the short to medium term. However, in the long-run, efforts should be geared towards increasing the use of primary energy, thereby reducing the percentage share of fossil fuel in total energy consumption.

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World Development Indicators, 2015 (WDI, online-version)

NOTES

[1] World Development Indicator, 2015 (online version) and Energy Information Administration (EIA) database.

[2] GDP and capital stock (Gross fixed capital formation) are measured in per capita US Dollars (2005=100) while labour is in units.

[3] Natural gas is measured in billion Cubic feet, petroleum in thousand barrels per day and energy use in kg of oil equivalent per capita.

[4] Note: 1= Algeria; 2=Angola; 3=Congo Republic; 4=- Egypt; 5=Gabon; 6=Nigeria; 7=South Africa. Total primary energy consumption in quadrillion Btu; dry natural gas consumption is measured in billion Cubic feet, total petroleum consumption in thousand barrels per day, total primary energy consumption in quadrillion Btu, total energy consumption in kg of oil equivalent per capita.

[5] According to Charnes, Cooper and Rhodes, 1978, in the DEA model of CRS, the more the increases in the inputs or the production factors used in the productive process, the more the increases in the output produced at an equivalent quota.

[6] The rank was based on the country average.