Research Article

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Increased Fossil Fuel Consumption and Its Impact on Energy Efficiency and Economic Growth

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Abstract

Energy efficiency improvement is believed to be an effective means of reducing energy consumption thereby reducing green-house gas emission and as well promoting sustainable economic development. Therefore, ascertaining the energy efficiency level will guide policy makers on the right kind policy intervention that will guarantee energy security, climate change mitigation and sustainable growth and development. The study employed a multivariate regression technique to estimation of the impact of a change in the energy structure on aggregate energy efficiency and economic growth. It was revealed in the study that, though an increase usage of fossil fuel is an important factor input for economic growth, however, it is inimical to the efforts aimed at combating climate change. The study also revealed that the marginal efficiency of the energy inputs is important for ensuring increased output as well as sustainable energy supply. Energy efficiency was seen as a mechanism for improving optimal energy utilization. Therefore, improving the level of energy efficiency will significantly assist in providing clean energy coupled with achieving sustainable development goals. This will benefit the nation in terms of ensuring energy security together with climate change mitigation. Policy makers should also focus more on investing in energy efficiency promoting technologies in order to reduce the per capita energy consumption without compromising the economic output level.

Keywords: *economic growth, energy, efficiency, sustainable development, South Africa*

1. Introduction

In recent discussions on energy and energy security, there has been a continual call for cheaper sources of energy, Climate change mitigation as well as environmental sustainability (Ilesanmi, 2015). Energy consumption is currently believed to be highly dependent of fossil fuel which accounts for about 84 % of the global greenhouse gas emissions in 2009 (OECD, 2011). There has been a rapid increase in the global demand for energy due to continuous increase in population and economic growth, particularly in

emerging markets economies. These growths in population and economy is expected to account for 90% of energy demand growth to 2035 (OECD, 2011). Energy efficiency improvement is believed to be an effective means of reducing energy consumption thereby reducing green-house gas emission and as well promoting sustainable economic development (Ilesanmi, 2015; Ilesanmi & Tewari, 2015; R Inglesi-lotz & Pouris, 2012; Roula Inglesi-lotz & Blignaut, 2011). Accordingly, the main aims of the sustainable development goals (SDGs) are to double the rate of improvement in energy efficiency as well as to enhance international cooperation to facilitate access to clean energy by 2030.

For the last decade, the world economy (especially China and India) and energy consumption have witnessed tremendous growth (Kaygusuz, 2012). The world's gross domestic product (GDP) rose from $46 trillion in 2005 to $74 trillion in 2013, with an average annual increase of 6.30 percent (*World Development Indicator 2014*, 2014). Similarly, energy consumption rose from 10, 714.4 million tons of oil equivalents to 12, 730.43 million tons of oil equivalents for the same period - an annual increase of 2.19 percent (*BP Statistical Review of World Energy*, 2014). All things being equal, the world's economy is expected to expand by 300% by 2050 which tends to generate 80 % increase in energy consumption (OECD, 2012). In this respect, if there is a lack of appropriate energy efficiency policy response, CO_2 emissions will double.

While the global picture hides much of the details between countries, to understand the diversity among these countries, it is worth observing the per capita GDP and energy use per capita GDP. Energy consumption per unit of output has changed over the last two decades. This can be attributed to economic structure, technological improvement and inter-fuel substitution. According to (Gillingham et al., 2009) "during the course of economic development, changes in the structure of GDP will lead to rising then declining energy use", although long-run series for energy and output should be treated with caution due to inherent development characteristics that appear (Richard et al., 1981). Energy consumption per unit of output for the United States and some emerging economies between 1990 and 2012 (purchasing power parity (PPP)) is illustrated in Figure 1.

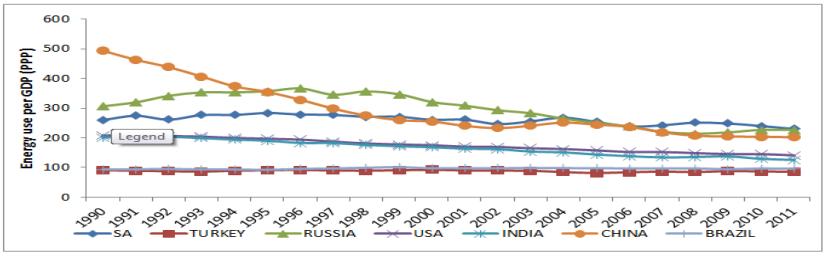

Figure 1: Energy Consumption per Unit of Output (1990-2011)
Source: Constructed based on data retrieved from (*World Development Indicator 2014*, 2014).

The long-run trend clearly indicates a downward movement which means that lower energy is required per dollar of GDP as the economy develops. The reason for this is that most of these countries are in their post-industrial stage of economic development (Joanne & Lester, 2009).

South Africa accounted for about 30 percent of the total primary energy consumption in Africa in 2012 (*BP Statistical Review of World Energy*, 2013). It required 0.24 tons of oil equivalents to produce US$1000 dollars at purchasing power parity (PPP) of GDP in 2001 (*World Energy Outlook 2014 Factsheet Energy in Sub-Saharan Africa Today*, 2014). Although, it is believed that energy consumption is one of the major factors of economic growth (Ilesanmi and Tewari, 2017; Joshua and Bekun, 2020), there is need for caution as this might be inimical to the environment. Particularly, Joshua and Bekun, 2020 concluded that although coal consumption is key to the growth of the South African economy, it also impact negatively on the environment. South Africa has implemented a series of energy policies especially regarding wider access and high quality electricity since the

emergence of a democratically elected government and they are specifically designed to provide basic services to the poor and disadvantaged that form the majority of the population. This includes the 1998 White Paper on energy policy, the 2003 White Paper on renewable energy, the national electrification programme, accelerated electrification, and several energy efficiency policies.

Although there are a number of studies (Fawkes, 2005; R Inglesi-lotz & Pouris, 2012; Inglesi & Blignaut, 2011; Rankin & Rousseau, 2008; Sebitosi, 2008) on energy efficiency in the South African context, this study differs in the sense that it covers a wider data period (1980-2018) unlike the study of (R Inglesi-lotz & Pouris, 2012; Roula Inglesi-lotz & Blignaut, 2011)). This study also extends other studies by examining the impact of the changed in the energy structure on energy efficiency level and as well as its impact on economic growth. Ascertaining the energy efficiency level will guide policy makers on the right kind policy intervention that will guarantee energy security, climate change mitigation and sustainable growth and development (Ilesanmi & Tewari, 2015). The remainder of the study is arranged as follows: Section 2 presents a conceptual review on energy consumption and economic growth, while, the empirical literature review is presented in Section 3. Methodology and data as well as results and discussion are presented in Section 4 and 5 respectively. Lastly, conclusions and recommendation is presented in Section 6.

2. Conceptual Review: Energy Consumption and Economic Growth

There are two perspectives whereby the relationship that exist between energy input and growth can be examined namely; energy efficiency and energy intensity. These two dimensions reflect an identical measure of the link between energy consumption and economic growth but from different perspectives (Yi-Ming et al., 2010). Energy intensity, from the perspective of energy demand is based on how economic output consumes energy resources. While on the other hand energy efficiency; from the perspective of factor supply is based on how energy resources support economic growth.

2.1 Energy Efficiency

Energy efficiency improvement according to (Kaygusuz, 2012) "is the cheapest and most environmentally friendly way to meet a significant portion of the world's energy need". It is also seen as a mechanism for reducing energy dependence and meeting energy sustainability goals although there are still disputes about how the economy responds to such efficiency improvement (Stern, 2011). Energy efficiency is an important element in energy policy and has received renewed attention in the wake of the global policy debate on climate change. Policy makers believe that reduction of energy demand is essential to achieving these goals. Energy efficiency is the extent to which energy resources supports economic output. At the aggregate level or whole economy, energy efficiency is measured as the level of gross domestic product per unit of energy consumed in its production (Gillingham et al., 2009).

Energy efficiency is mainly driven by improved technology. However, it must be noted that different energy resources have different abilities in supporting the economy which means that the total energy efficiency can also be affected by change in the energy structure (Yi-Ming et al., 2010). Figure 2 presents the energy efficiency trend in South Africa between 1980 and 2012.

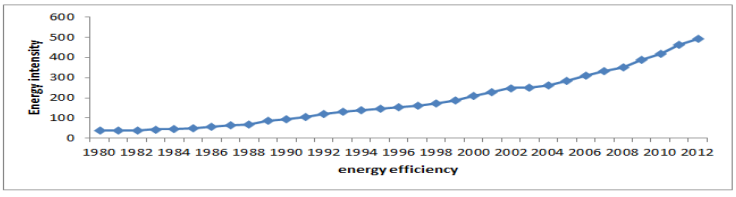

Figure 2: Energy Efficiency in South Africa (1980-2012)
Source: Constructed from data retrieved from (Bank, 2014; *BP Statistical Review of World Energy*, 2013)

Energy efficiency in South Africa had witnessed a continuous increase over the years. Despite the progress that has been made, future energy measure lies in the field of energy efficiency.

2.2 Energy Intensity

Energy intensity refers to the amount of energy that is required to produce a single unit of GDP or, in order words, the total energy consumption input to produce a unit of economic output. High energy intensities indicate a high price or cost of converting energy into GDP, vice versa. For the past 20 years South Africa's energy intensity had witnessed a continuous and steady decline although it is still four times higher than OECD countries (Hawkes, 2005: 19). The energy intensity trend from the period under review is presented in Figure 3.

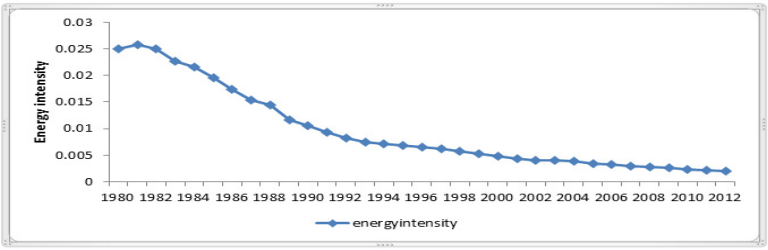

Figure 3: Energy Intensity in South Africa (1980-2012)
Source: Constructed from data retrieved from (Bank, 2014; *BP Statistical Review of World Energy*, 2013)

The fact that the economy was growing and energy intensity declining may attract some serious questions as to the underlying factor behind the steady decline in energy intensity. We might assume that as the economy grows, the share of energy consumption for each unit of output should rise. However, it must be noted that the decline in energy intensity in South Africa is largely due to the economy's structure being dominated by the service sector as well as technological advancement.

3. Literature Review

Energy crises in the early 1970's which contributed to reducing economic growth in many countries increased concerns about whether or not to implement energy conservation policy as well as placing emphasis on the danger of dependence on exhaustible resources (Jamil & Ahmad, 2010; Lee & Oh, 2006; Richard et al., 1981). Although energy is an essential input for economic growth and development, two major drawbacks have emerged in the way energy resources are sourced, produced and used (Davidson et al., 2006). First, the overall energy system specifically in South Africa has been very inefficient, with the efficiency index standing at 38 percent in 2009 (Union, 2015). Secondly, there are different social and environmental problems, both local and global, which have affected with the energy system. In addition to that, "the mechanisms of the energy sector have a huge impact on the social life of people. This is because most of these energy sources usually lead to dislodgement of people and as well worsen or aggravate the level of social class differences in the society. Therefore, limiting the environmental and social impact of the various energy sources is of a major concern for stakeholders in the energy sector (Davidson et al., 2006).

Due to increasing modernization and reliance on information and communication technologies (ICTs) and other appliances such as computers, cell phones etc., there have been an increased demand for energy by households and companies. As noted earlier, the demand for energy is as a result of several factors such as increase in population, increase in the living standard of the people, urbanization as well as industrialization. (Gurgul & Lach, 2012). Other literatures that show that

energy support growth are discussed below.

Chiou-Wei et al., (2008) examined the relationship between energy consumption and economic growth in a sample of Asian newly industrialized countries as well as the USA using both linear and nonlinear Granger causality tests. Empirical evidence shows that energy consumption drives economic growth for Taiwan, Hong Kong, Malaysia and Indonesia. (Tsani, 2010) investigated the relationship between aggregate and dis-aggregate levels of energy consumption and economic growth. Her findings suggest that energy supports GDP at the aggregate level.

Also, Yildirim & Aslan (2012) examined the causality between energy consumption and economic growth in a number of countries (Turkey, Bangladesh, Egypt, Indonesia, Iran, Korea, Mexico, Pakistan, and the Philippines) using the bootstrapped autoregressive metric causality approach. Estimating a trivariate model consisting of GDP per capita, energy consumption per capita and gross capita formation, the growth hypothesis was supported in the case of Turkey, as a unidirectional causal relationship was found running from energy consumption to economic growth. Other studies (Akinlo, 2009; Ilesanmi & Tewari, 2017; Odhiambo, 2009; Soytas & Sari, 2003; Yuan et al., 2007) using various techniques and data and countries including South Africa also confirm that energy support economic growth. Energy efficiency strategies are therefore aimed at reducing energy consumption without reducing its use by the various sectors of the economy. That is, reducing energy usage without compromising economic output.

4. Methodology and Data

4.1 Unit Root Test

This study performs the augmented Dickey and Fuller unit root tests to check for the presence of unit root among the variables. The null hypothesis of no unit root is tested against the alternative hypothesis which confirms the presence of unit root in the variables.

A non-stationary variable is differenced successively to ensure the stationarity of the variable and also to know the order of integration of the variable. The ADF test accounts for situations where the error terms, μ_t are correlated based on the assumption that the error term is independently distributed.

In line with the study of Gujarati and Porter (2009), the ADF test the following regressions were estimated: $\Delta Y_t = \delta Y_{t-1} + \sum_{i=1}^{m} \alpha_i \Delta Y_{t-i} + \mu_t$ (1), $\Delta Y_t = \beta_0 + \delta Y_{t-1} + \sum_{i=1}^{m} \alpha_i \Delta Y_{t-i} + \mu_t$ (2), $\Delta Y_t = \beta_0 + \beta_2 t + \delta Y_{t-1} + \sum_{i=1}^{m} \alpha_i \Delta Y_{t-i} + \mu_t$ (3), where μ_t = error term.

The main difference amongst equations 1 – 3 is the existence of deterministic elements β_0 and $\beta_2 t$. As a matter of procedure, Equation 1 is first estimated and after which the appropriateness of the model is tested before moving to the next model (Asteriou & Hall, 2007). It must also be noted that in the ADF test, the Dickey Fuller's test is adjusted to account for possible serial correlation in the error term by adding the lagged difference terms of the regressand.

4.2 Impact of South Africa's energy structure on energy efficiency

Similar to the study of (Yi-Ming et al., 2010) in the case of China, this study examined the impact of South Africa's energy structure on energy efficiency. Energy resources include coal, oil and natural gas which are all measured in million tons of oil equivalents. The use of a similar measurement of oil equivalent implies that different energy resources will produce the same economic output. Generally, energy efficiency is measured as the ratio of economic output to energy resource input which is expressed in Equation (7) below.

$ef = \frac{GDP}{EN}$ (7) where GDP means gross domestic product and EN means energy input. Let us assume that $EN_{(i=1,2,3,....)}$ represents the input of different energy resources, that is, coal (CL), oil (OL) and natural

gas (NG) respectively, and $GDP_{i\,(i=1,2,3,....)}$ represents sector-wise economic output supported by different energy resources. Thus, we can formulate the energy efficiency model of different energy resources as follows: $ef_i = \frac{GDP_i}{EN_i}$ (8) (i=1,2,3,....) from Equation (2) making GDP the subject of the formula we have $GDP = \sum ef_i \times EN_i$ (9) (i=1,2,3,....) therefore, the aggregate energy efficiency ef can be formulated as $ef = \frac{GDP}{EN} = \sum ef_i \times \frac{EN_i}{EN} = \sum ef_i \times S_i$ (10) (i=1,2,3,.....) , where S_i represents the share of different energy sources in the total energy input, that is, $\frac{EN_i}{EN}$.

Using a multivariate regression model for the estimation of the impact of energy structure on aggregate energy efficiency we use the regression model formulated by Yi-Ming et al., (2010)

$ef = \sum_i a_i * S_i + \varepsilon$ (11)

To allow for increase in energy efficiency due to improvement in technology, we introduce t variable in the model with the assumption that the time element is linear, that is t=1, 2, 3,....., n. We can therefore re-formulate Equation (11) above as follows:

$ef = b * t + \sum_i a_i * S_i + \varepsilon$ (12) where:b *and* $a_i$are coefficients of the regression equation.

Marginal efficiency (ME) of energy in South Africa

It is quite important to also estimate the marginal efficiency of the energy resources. It reflects the percentage increase in output for each additional unit increase in energy input used. The ME model is represented in Equation (13) as follows: $dGDP_t = \alpha_1 + \alpha_2 GDP_{t-1} + \alpha_3 dE_{it} + \varepsilon$ (13)

Where $dGDP_t$ = increment of economic outputs between the year (t) and (t-1); $dGDP_{t-1}$ = the economic outputs in the year (t-1); dE_{it} = increment of the input of energy resources between the year (t) and (t-1).

The data used in this study includes gross domestic product (GDP), coal consumption (CL), natural gas (NL), oil consumption (OL), and total energy consumption (EC). The data on GDP was sourced from world development indicator, while, energy data was sourced from BP statistical review. The study period is from 1980 to 2018.

5. Results and Discussion

5.1 Summary Statistics

The summary statistics result is presented in Table 1. From the result, it can be seen that the mean and median and almost equal which implies that the distribution is symmetrical. This is also confirmed by the skewness values for all the variables which are close to zero. The Jarque Bera (JB) test shows that all the variables used in the model are normally distributed since they are all less than the chi-square (5.99, 2df) critical value at 5 percent significance level.

Table 1: Summary Statistics

	LNEC	LNOL	LNNG	LNCL	LNGDP
Mean	4.582987	3.006904	0.014005	4.294145	9.726894
Median	4.599620	3.073420	-0.043090	4.304610	9.852247
Maximum	4.830420	3.327480	1.532700	4.541420	11.00391
Minimum	4.010020	2.483490	-1.608490	3.754460	7.698483
Std. Dev.	0.212815	0.262723	1.179579	0.180065	1.058058
Skewness	-0.669994	-0.504232	-0.144858	-0.780110	-0.421482
Kurtosis	2.785306	1.864897	1.537693	3.533555	1.906939
Jarque-Bera	2.992704	3.746369	3.611200	4.418319	3.096227
Probability	0.223946	0.153634	0.164376	0.109793	0.212649
Sum	178.7365	117.2693	0.546212	167.4716	379.3489
Sum Sq. Dev.	1.721027	2.622880	52.87347	1.232085	42.54049
Observations	39	39	39	39	39

5.2 *ADF Unit root test*

The ADF unit root tests indicate that all the variables are not stationary at levels. That is, they exhibit unit root. This is as a result of the fact that the estimated test statistic of all the variables are less than their critical values. In order words, the t-statistics values are not more negative than their critical values based on the 5 % significance level. The unit root test was then further estimated at first difference. Based on the result as presented in Table 2, the result indicate that all the series are all stationary at first difference. This therefore, implies that all the series are integrated of the first order I(1).

Table 2: ADF unit root test

Variables	T statistic	Critical value (5%)	Lag length	Integrated order
D(GDP)	-4.548317	-3.562882	0	I(1)*
D(EC)	-5.229000	-2.960411	0	I(1)*
D(COL)	-4.776846	-3.562882	0	I(1)*
D(NG)	-4.233449	-3.562882	0	I(1)*
D(OL)	-4.524109	-2.971853	3	I(1)*

Using data on South Africa's energy component, and economic growth from 1980-2018, a regression equation of the impact of energy structure on aggregate energy efficiency was estimated as follows:
$ef = 0.027t + 0.157LNCL + 0.157LNNG + 1.310LNOL + \varepsilon$ (8), (p = 0.0002), (p = 0.4310),(p = 0.005), (p = 0.0001), R^2 = 0.98

All the variables pass the significance test at 5 percent level of significance except the coefficient of coal consumption which failed to pass the test. This implies that there exists no significant relationship between coal consumption and energy efficiency for the period of the study (1980-2018). Therefore, it was excluded from the model and re-estimated. Using the same data set, the following result was found: $ef = 0.025t + 0.138LNNG + 1.542LNOL + \varepsilon$ (9), (p = 0.0002), (p = 0.0059), (p = 0.0000), R^2 = 0.98.

The coefficients of the energy component pass the significance test at the 5 percent level of significance. This indicates the extent to which changes in the energy component affect South Africa's energy efficiency. A unit increase in crude oil and natural gas consumption increases the total energy efficiency by 0.138 and 1.542 million tons of oil equivalents. It is also evident that technological development contributes positively to energy efficiency level in South Africa. This implies an improvement in the level of technology over the years in a bit to reduce energy consumption per capita output. Furthermore, estimating the impact of a change in the energy input and total energy consumption on the output level, we get the regression Equations 10 - 13.

$dGDP_t = -10.969 + 1.090\text{GDP}_{t-1} + 35.556dOl_t + \varepsilon$ (10), (p = 0.0008) (p = 0.0008) (p = 0.0009)

R2 = 0.36, $dGDP_t = -9.379 + 0.980GDP_{t-1} + 12.851dCl_t + \varepsilon$ (11), (p = 0.0082) (p = 0.0065)(p = 0.0695), R = 0.21.

$dGDP_t = -6.896 + 0.759GDP_{t-1} - 1.234dNG_t + \varepsilon$ (12), (p = 0.0379) (p = 0.0267) (p = 0.4563), R = 0.12.

$dGDP_t = -10.947 + 1.118GDP_{t-1} + 22.459dEC_t + \varepsilon$ (13), (p = 0.0020) (p = 0.0017) (p = 0.0096)

R = 0.21.

The coefficient of dE is the ME of factor inputs. That is 1mtoe of oil can produce economic output of R35.55 million. This result presented in Equations 10, 11 and 12, which examined the impact of the marginal efficiency of the energy inputs on output, revealed that there is a positive and significant relationship between the increment in energy inputs such as crude oil and coal and economic output, though coal only passed the 10 percent significance test. This is in line with the study of Joshua and Bekun (2020) who asserted that increase in coal consumption is key for economic expansion. This

implies that an increase in the efficient utilization of energy resources will bring about economic growth and sustainable energy supply. The marginal efficiency of the energy inputs is important for ensuring ensuring increased output. Furthermore, it was revealed that though natural gas does contribute positively to the nation's efficiency level, it was found not to significantly affect economic growth. The marginal efficiency of natural gas on output estimated in Equation 12 with p-value of 0.45 indicates that it does not significantly influence economic output. This may be partly due to the fact that the share of gas among the various energy inputs is minimal compared to others.

Turning to the marginal efficiency of the aggregate energy consumption and its impact on economic output, it was revealed that total energy consumption has a high impact on economic growth (See Equation 13). This is similar to the study of Pinitjitsamut (n.d), Chiou-Wei et al., (2008), Yildirim & Aslan (2012) and Ilesanmi and Tewari (2017). This therefore, implies that a unit increase in aggregate energy consumption as a factor input per 1,000 mtoe in the production process, economic output will increase by R22.46 million.

It was also revealed that technology has a positive influence on efficiency. All model passed the diagnostic test and the CUSUM stability test is presented in the appendix.

6. Conclusions and Recommendations

Energy efficiency and energy intensity in South Africa were examined together with their impact on economic growth. The study revealed that increase usage of fossil fuel is inimical to the efforts aimed at combating greenhouses gas emission (GHG), global warming and environmental sustainability. Energy efficiency was seen as a mechanism for improving optimal energy utilization. The study revealed that natural gas and oil has positive influence on energy efficiency. This means that a continual increase in fossil fuel consumption reduces the efficiency level of the energy inputs. The study also revealed that the marginal efficiency of the energy inputs is important for ensuring increased output as well as sustainable energy supply. Therefore, improving the level of energy efficiency will significantly assist in providing clean energy coupled with achieving sustainable development goals. This will benefit the nation in terms of ensuring energy security together with climate change mitigation without jeopardizing their output growth potentials. This mean, government should focus more on investing in energy efficiency promoting technologies in order to reduce the per capita energy consumption without compromising the economic output level. Further study can consider the use of more sophisticated econometric technique such as the data envelopment analysis to measure sectorial base efficiency level.

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Appendix 1: