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THE EFFECT OF CO2 EMISSION AND ECONOMIC GROWTH ON ENERGY CONSUMPTION IN SUB SAHARA AFRICA

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ABSTRACT

The relationship among CO2 emission, Economic Growth and Energy Consumption were examine in this study. This study specifically examines the combine impact CO2 emission, and Economic Growth on Energy Consumption. The study uses a dynamic panel data of esteem the time series analysis on 1980. Our result shows that Economic Growth is positively related to Energy Consumption. But when CO2 emission is interacted with Economic Growth the combine impact is increasing in energy consumption. The study therefore recommend that appropriate policy should formulated by the government to drive up energy consumption.

Contribution/ Originality: The paper contributes the first logical analysis in the existing literature of the relationship between Co2 emission, economic growth and energy consumption. The study departs from other studies by examining the combined impact of Co2 emission and economic growth on energy consumption in Sub-Saharan African countries during the period of the study. There is also robust use of system GMM developed by Arellano and Bond (1991) which gave consistent and efficient estimates.

1. INTRODUCTION

Detailed and historical validation has provided comprehensive empirical evidence on the relationship among CO_2 emission, economic growth and energy consumption use. Notable among these studies are (Stern and Cleveland, 2004; Sahir and Qureshi, 2007; Apergis and Payne, 2009; Apergis and Payne, 2010; Zaleski, 2014; Soytas *et al.*, 2015) etc. Vast literature has written extensively on the relationship between energy consumption and economic growth. For instance, Li (2003) and Cheng (2013) studies on the relationship between energy

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consumption and economic growth but discovered the existence of unidirectional causality between energy consumption and economic growth running from economic growth to energy consumption. Similarly, Chan and Lee (2014) study on the relationship between energy consumption and economic growth using vector error correction model technique and cointegration to analysis on china's energy consumption behaviour. Their result revealed that energy price is a driver of energy consumption.

Against this background, this study departs from other studies because it considers the combine impact of CO_2 and GDP growth on energy consumption.

2. BRIEF REVIEW OF LITERATURES

The literature on the relationship among CO_2 emissions, economic growth and energy consumption can be viewed from four different angles namely how GDP affect energy consumption, how CO_2 emissions affect energy consumption and the interactive impact of GDP and CO_2 emissions on energy consumption.

Wei (2002) examine the long-run equilibrium relationship between energy consumption and some macroeconomic factors such as energy price, income and the share of heavy industry in the GDP and discovered that all the variables are cointegrated. Also, a reverse chain of causality from income to energy with then signifies a less energy-dependent economy such that energy conversation policies may be realized with little effects on income. On a panel of six countries of the Gulf Cooperation Council, Wei (2002) study on the relationship energy consumption and GDP using Johansen cointegration test but discovered that energy consumption and GDP are cointegrated.

Similar study conducted by Squalli (2007) suggests the possibility that an increase in energy consumption may have a negative impact on the GDP, such a possibility could result from excessive energy consumption.

Indeed, Chang (2009) study on the relationship between energy consumption and economic growth using the panel threshold regression (PTR) model OECD countries over the period 1997-2006, observed that the level of economic growth of a country influences the use of energy. Furthermore, studies by Bartleet and Gounder (2016) on the casual relationship between energy consumption using multivariate models. The study concluded that economic growth causes energy consumption and economic activity determines the increase in energy demand .In another study conducted by Li *et al.* (2011) for a sample of 30 provinces in China testing the long-run co – integrated relationship between the real GDP per capita and energy consumption. They found a positive long-run co-integrated relationship between the variables. Shabbier *et al.* (2014) investigates the relationship between Renewable and Nonrenewable Energy Consumption, Real GDP and CO_2 Emissions, using the Structural VAR Approach method in Pakistan. Their results revealed that in the short-term, rising energy with the help of non-renewable and renewable energy consumption raises real GDP up in the short-run. On the other hand, the relationship between CO_2 emissions and energy consumption has also been discussed by a number of studies. Notable among these studies are Shyamal and Rabindra (2016) who uses a decomposition method, by examining the factors that influence the level of energy-related CO_2 emissions. They discovered that CO_2 emissions in the industrial sector demonstrated a decreasing trend due to consumption and fuel switching.

Lean and Smith (2009) examined the casual relationship between carbon dioxide emissions and energy consumption using a panel vector error correction model for five ASEAN countries over the period 1980-2006. The long-run estimate indicates that there is a statistically significant positive association between energy consumption and emissions. In Iran, one-way casual relationship exist between energy consumption (Petroleum products and natural gas consumption) to CO_2 emissions. However, there was no casual relationship running from fossil fuels energy consumption and emissions. Moreover, there was no evidence that CO_2 emission, petroleum products, fossil fuels consumption led to economic growth (Lotfailpour *et al.*, 2010). Similarly, in South Africa, Menyah and Rufael (2010) found a positive effect of CO_2 emissions on energy consumption. Also, show a positive relationship between energy consumption and CO_2 emissions in eight Asian economies. Despite although the use of the CO_2 emissions per capita and energy consumption in the developing countries is much lower than it is in the developed ones, Arouri *et al.* (2012) used the bootstrap panel unit root tests and co-integration techniques to investigate the relationship between carbon dioxide emissions, energy consumption, and real GDP for 12 Middle East and North African countries (MENA) over the period 1981-2005. Their results show that in the long-run, there is a positive significant impact of energy consumption on CO_2 emissions. Shahbaz *et al.* (2014) investigated the non-linear relationship between foreign direct investment and environmental degradation using panel data of 110 developed and developing economies. The results indicated that environmental Kuznets curves exists and foreign direct investment increases environmental degradation.

3. ECONOMIC MODELLING AND DATA

3.1. Impact of CO_2 Emissions and Economic Growth on Energy Consumption

While CO_2 emissions has the prospective to control economic growth through a host of channels, in this set of regressions, we examine specific link between CO_2 emissions and energy consumption specifically that working through economic growth the hypothesis we would like to test is whether the level of economic growth affect the impact of CO_2 emissions on energy consumption. And, to this end we interact CO_2 emissions with economic growth and test for the significance of the interacted coefficient. In order to ensure that the interaction term does not proxy for, these variables are also included in the regression separately. A negative coefficient would indicate that a CO2 emission is more effective in boosting growth. In other words, a negative interaction provides evidence of substitutability between energy consumption and economic growth indicators. On the other way round a positive interaction would imply that the growth effects of CO_2 emissions are enhanced in better economic growth, supporting complementarities of CO_2 emissions and economic growth indicators. The CO_2 emissions growth nexus extends equation (22) to include the interaction term. The parametric CO_2 emissions and economic growth – growth model can be written as

$$Y_i,t = \alpha Y_1, t\text{-}1 + \Psi(CO_2{*}EG)_{i,t} + \Psi^1 X_{i,t} + \epsilon_{i,t} \quad (1)$$

Where y is the logarithm of real per capita GDP, x represents the set of explanatory variables (other than the lagged per capita GDP and indicators of CO_2We choose lagged explanatory variables instruments. This equation (24) can be written as

$$(CO_2{*}EG)i,t = b^1 Zi,t\text{-}1 + Ui,t \quad (2)$$

Where Z represents all the explanatory variables in
We assume E (ϵi,t/Zi,t-1 Ui,t) = E(ϵi,t/Ui,t). This then follows that E (ϵi,t/Ui,t) ≠ 0, since E(ϵi,t/EE*Gvnce) ≠ 0. Hence, one can decompose Ei,t into ϵi(Ui,t) + ϵi,t, where ϵi(Ui,t) = E(ϵi,t/Ui,t) and ϵi,t = ϵi,t – E(ϵi,t/Ui,t). Equation (3) becomes

$$EC_i,t = \alpha EC_1,t\text{-}1 + \Psi(CO_2{*}EG)_i,t + \Psi^1 X_i,t + \epsilon_i(Ui,t) + \epsilon i,t \quad (4)$$

We then replace the unobservable Ui,t by the observable Ui,t = $(CO_2{*}EG)i,t - \Psi^1 Zi,t\text{-}1$
Then equation (4) becomes

$$EC_i,t = \alpha EC_1,t\text{-}1 + \Psi(CO_2{*}EG)_i,t + \Psi^1 X_i,t + \epsilon_i(Ui,t) + \epsilon i,t \quad (5)$$

where the error

$\epsilon i,t = \epsilon i,t + \epsilon i(Ui,t) - \epsilon i(Ui,t)$

So, one can use Arellano and Bond (1991) two-step version of Arellano and Bond (1991) weighting matrix estimators to obtain consistent estimation of α and Ψ . Then, substitute α and Ψ into equation (5) which becomes

$$EC_i,t = \alpha Y_{1,t-1} + \Psi(CO_2{*}EG)_{i,t} + \Psi X_{i,t} + \epsilon_i(U_{i,t}) + \epsilon_{i,t} \quad (6)$$

Where Єi*,t* represents the new composite error term that account for the estimation of α and Ψ, we then use the weighting estimators propose to obtain consistent estimates of f(EE*Gvnce)i,t and Єi(Ui,t), say f(CO_2*EG)i,t and Єi,t(Ui,t). It is of course f(CO_2*EG)i,t, the estimated function we are interested in, since the marginal effects of the governance indicator variable on per capita growth clean of any endogeneity. Then, the specific regression to be estimated is as follows:

$$ECit = \Psi_0 + \Psi_1 EG_{,t} + \Psi_2 EGi,t\text{-}1 + \Psi_3 GPIPE_{i,t} + \Psi_4 FDI_{,t} + \Psi_5 POP_{,t} + \Psi_6 E_{i,t} + \Psi_7 EG_{,t} + \Psi_8(CO_2{*}EG)_{I,t} + Vit + U_{it} \quad (7)$$

Where CO_2*EG is interactive variable; and EG is the economic growth indicators.

EG– economic growth according to many researchers there exist a consensus opinion regarding the importance of good governance for economic growth. Majority of the empirical studies have come to the conclusion that sustained economic growth could be accelerated by the importance of institutions and implementing sound economic policies that could be the basis of enhanced efficiency of the factors of production. This study therefore, we expect the relationship between the phenomenons to be positive. CO_2 *EG. The coefficient of this interactive variable could be positive or negative.

3.2. Source of Data

The data use in this study are taken from the World Development Indicator (WDI, 2013) and cover 1990-2012. The variables use are the energy consumption (measured in kilogram (kg) of oil equivalent per capita), CO2 emissions (measured in metric tons per capita), economic growth (proxied in GDP per capita (constant 2005 USS), capital stock (measured by gross fixed capital information (constant 2005 USS), financial development (total credit to private sector as a ratio of GDP), Labor, and POP refers to the total population. The specific countries selected for the study and the timeframe was dictated by data availability. sub-Saharan region, consisting of 21 countries, namely: Algeria, Botswana, Cameroon, Congo, Cote D'Ivoire, Ethiopia, Gabon, Ghana, Egypt, Iran, Jordon, Kenya, Morocco, Mozambique, South Africa, Senegal, Sudan, Syrian Arab Republic, Togo, Tunisia, and Zambia.

The descriptive statistics mean, standard deviation (Std. Dev) and the coefficient of deviation (CV) of these variables are recorded below in Table1, CO2 emissions is measured in metric tons per capita.

Table-1. Descriptive statistics by panels of countries

Variables	Mean	Std. Dev	CV
All sample countries			
Energy consumption per capita	5.775	68.222	12.36
GDP per capita	25.475	381.581	13.443
CO_2 emissions per capita	24.506	392.077	14.481
Financial development	71.629	61.459	0.811
Capita stock	21.632	223.659	12.662
Population	18. 037	292. 391	14.569
Middle Eastern, North African and sub-Saharan region			
Energy consumption per capita	2.730	44.648	16.354
GDP per capita	8.432	127. 934	15.172
CO_2 emissions per capita	25.340	325.035	12.026
Financial development	37.004	39.930	1.079
Capita stock	9.160	101. 657	11.097
Population	5.150	48. 239	9. 366

Notes: Std dev. And CV indicates deviation and coefficient of variation (standard deviation – to –mean ratio), respectively.

The mean growth rate of CO2 emissions per capita is the highest in the global countries, Moreover, the average growth rate for GDP per capita are recorded highest global panel, followed by sub-Saharan/North Africa and Middle East, Europe and North Asian region, and latin American and Caribbean. It is also noted that sub-Saharan/ North Africa and Middle East are more volatile in GDP per capita; its variation is 15.172, which is the highest when compared to other panel countries coefficient of variation.

Table 2 shows the correlation matrix. The correlation between economic growth and energy consumption is positive. Capital is positively related to the GDP. The relationship between population and economic growth is positive. The relationship between capital stock and population is negative. The correlation indicates a positive correlation between the CO_2 emissions and the other

Variables. Financial development is positively correlated with the population, economic growth, CO_2 emissions and capital. A negative correlation exists between population and energy consumption.

Table-2. Correlation matrix

	gENRC	gGDP	gCO_2	gPOP	gCO_2	FD
gENRC	1.0000					
gGDP	0.6781	1.0000				
gCO_2	0.8549	0.9413	1.0000			
gPOP	-0.0070	0.0102	0.8823	-0.00039	1.0000	
Gk	0.6842	0.8165	0.7823	-0.0039	1.0000	
FD	0.5479	0.00342	0.0257	0.0219	0.0186	1.0000

Source: Authors Computation 2017

3.3. Analysis and Discussion

In the present study, we used a dynamic panel specification where lagged levels of the energy consumption are taken into account by using the Arellano and Bond (1991) GMM estimator. Our proposed model is as follows:

$$gENRC_{i,t} = \beta o gENRC_{i,t} + \beta gGDP_{i,t} + \gamma gCO_{2\,i,t} + \sum_{j=1}^{3} \Theta j z_{i,t} + \mu_{i,t};$$

$i = 1,..., N; t = 1, ..., T$ (8)

Where $gENRC_{i,t}$ stands for energy consumption rate of country i at time, βo is the parameter to be estimated; Control is a vector of core explanatory variables used to model energy consumption (capital stock, population, and financial development); μ is country –specific effects; and € is the error term. Finally, □ captures the effect of economic growth while ϒ captures that of the CO_2 emissions.

Eq. (5) is an example of a linear dynamic panel model (Arellano and Bond, 1991). These model contains the lagged dependent variables ($gENRC_{i,t-1}$) which are correlated with the error term. The use of panel ordinary least squares (OLS) estimator (with fixed and random effects) is problematic. Arellano and Bond (1991) developed a generalized method of moments (GMM) estimator which gives consistent parameter estimates for models of this type. In their approach, the unobserved firm-specific heterogeneity is eliminated by using a first differencing transformation. This removes the country – specific effects.

3.4. Main Results and Discussions

The lower panel of each table includes some post estimation tests of autocorrelation and instrument validity. AR (2) Arellano and Bond (1991) tests of second order autocorrelation in the first differenced errors. When the regression errors are dependent and identically distributed, first differenced errors are, by construction, auto-correlated. Autocorrelation in the first differenced errors at order is higher than the one that suggests that the

GMM moment conditions may be valid. Sargan test (Arellano and Bond, 1991) is a test of over identifying restrictions. A rejection from this test indicates that the model or instructions may be miss-specified. For each of the estimates reported in Table 3 -6, the AR (2) tests show no evidence of autocorrelation at conventional levels of significance. Sargan tests show no evidence of misspecification at conventional levels of significance levels. These results indicate that the dynamic panel energy consumption model is good specification.

The results of the global panels are reported in Table 3. The value of $ENRC_{,t-1}$ (-0.0016) implies that energy consumption is corrected by (0.160) present each year. We find that economic growth has positive and statistically significant effects at 1% level on energy consumption. The coefficient of economic growth is 0.445 implying that a 1% increase in the growth rate of the GDP per capita increase energy consumption by 0.445% for sample countries. The results here are consistent with these of a recent study on this subject by Aqeel and Butt (2001); Ghosh (2002) and Paul and Bhattacharya (2004); Morimoto and Hope (2004); Ghali and EL-Sakkka (2004); Oh and Lee (2004); Altinary and Karagol (2005); Ang (2008); Boedwn and Payne (2009); Odhimbo (2009); Belloumi (2009); Shahbaz and Lean (2012) and Omri (2013). Similarly, a CO2 emission has a positive and statistically significant at 1% level. A 1% increase in CO2 emissions is expected to raise energy consumption by 0.136%.

Table 3 shows that impact of the financial development on energy consumption is positive and significant at the 5% level. A 1% increase in domestic credit to private sector is expected to raise energy demand by 0.0027%. Financial development promotes investment, which raises energy demand due to economic growth. Easy access of credit enables consumers to purchase big ticket durable consumer items, and the usage of consumer items directly increases energy demand. Our finding is consistent with that of Karanfil (2009) and Sadorsky (2010). The coefficient of capital stock indicates that capital has a significant and positive effect on energy consumption at the 1% level. A 1% increase in capital enhances demand for energy consumption by 0.050%, ceteries paribus. This finding supports the view of Lee *et al.* (2008) For the panel estimation, the variable of population has a significant and positive effect on energy consumption at the 10% level. This suggests that a 1% increase in population raises energy consumption directly and indirectly by 0.013%

Table-3. Summary of the results for all four panels

	Middle Eastern, North African, and sub-Saharan region
Per capita CO_2 emissions	✓ (+)
GDP per capita	✓ (+)
Financial development	✓ (+)
Capita stock	✓ (+)
Population	✓ (+)

Source: Authors Computation 2017

Denotes statistical significance (+) denotes it has positive effect on the per capita CO_2.

Consumption at 10% level. This implies augmentation 1% raises energy consumption by 0.146%. Finally, the variable of capital and population has an insignificant impact on energy consumption.

Table contains results for the sub-Saharan/North African and Middle Eastern panel. The value of $ENRC_{t-1}$ (-0.0022) implies that energy consumption is corrected by (0.220) percent each year. The results show that the CO_2 emissions are statistically significant at the 1% level. The magnitude of 0.056 implies that a 1% increase of the CO_2 emissions increase energy consumption by 0.056%. It is found that economic growth has not a significant impact on energy consumption of the sub-Saharan/North African Middle Eastern panel. Similarly, the coefficient of financial development and capital are positively correlated (0.00020 and 0.053) but not significant. Finally, the coefficient of the population indicates that population has a significant and positive effect on energy consumption at the 1% level. A 1% increase in the population raises energy consumption by 0.519%.

Table 3 Summaries the results concerning the effects of CO_2 emissions and economic growth on energy consumption for the four panels. First, we have found that the effect of economic growth on energy consumption is positive and statistically significant in the four panels. This indicates that an increase in economic growth implies increase energy consumption. This result is generally consistent with whose of Siddiqui (2004); Khan and Qayyum (2007) and Barazini *et al.* (2013). Second, CO_2 emissions have a positive and statistically significant European and Asia, and for the Latin American and Caribbean region. Our results are in line with the findings of Dan and Lijun (2009); Karanfil (2009); Sadorsky (2010) and Tang and Tan (2012). Moreover, capital has a positive and statistically significant effect on energy consumption only for global panels. Finally, population has a positive and statistically significant effect on energy consumption only for the Middle Eastern, North Africa, and sub-Sahara.

4. CONCLUSION AND POLICY IMPLICATION

This study investigates the combine impact of CO_2 emissions and economic growth on energy consumption. The study comes up with the result that when positive association exist between energy consumption and economic growth. But when CO_2 an emission is interacted with economic growth an energy demand increase which implies that energy consumption and CO_2 emissions are complimentary.

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