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Energy Consumption and Manufacturing Industry Performance: Evidence from Panel Data for Low-Income Sub-Sahara African Countries

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Abstract **–** This paper examined the effect of energy consumption, capital and labour on manufacturing industry performance using panel data for the sample of seven low-income sub-Saharan Africa (SSA) countries during the period 1990-2012. The panel cointegration test provided evidence of cointegration among the variables for the seven low income-income SSA countries. The Fully Modified Ordinary Least Square (FMOLS) result indicated that energy consumption and capital formation are positively significant variables in explaining the performance of the manufacturing industry in the seven low-income SSA countries. Conversely, labour was insignificant in explaining manufacturing industry performance. For that, strong energy policy that will enhance efficient and sustainable energy supply should be put in place to enhance energy consumption in SSA countries.

Keywords **–** Energy consumption, manufacturing industry performance, sub-Sahara Africa.

1. INTRODUCTION

Energy is believed to have absolute role as a factor inputs in the process of production for many producers, as well as a final good for end users. The short run changes, as well as the long run economic activities trend affect the household and business's energy consumption, which by implication may affect an economy [1]. From the production point of view, the classical economist of the 17th and 18th centuries considered capital, land and labour as the primary factors in the process of production. Yet, the development of industrialized nations in the 19th century has recognized energy as an essential input in the process of production [2].

The interest of scholars to explore the relationship between energy consumption and economic growth is traced back to the energy consumption crisis of 1970s. This brought about the argument that energy consumption causes the growth of GDP. Since then, many studies such as; [3]-[6] were conducted to uphold the assertions that recommend energy consumption to be related with the growth of GDP positively. But, evidences from empirical perspectives were found to be conflicting and contradicting on the direction of causality [7].

This paper was aimed at examining the effect of energy consumption, capital and labour on manufacturing industry performance for seven low-income SSA countries (Benin, Congo DR, Cameroon, Kenya, Mozambique, Togo and Tanzania). The study was considered as a study relevant to the previous studies on the link connecting energy consumption with GDP. Moreover, the study is motivated owing to the fact that most of the SSA countries depend on importation of finished goods and there is the need to find out whether this over reliance of import in connected to poor manufacturing performance arising from energy consumption. Also, previous studies lay more emphasis on energy-GDP nexus and there is the need to examine this relationship from the manufacturing industry sector as increase in manufacturing industry performance lead to increase in GDP. Hence, this study therefore makes a significant contribution in the field of energy economics as it focuses on the performance of manufacturing industry which may affect economic growth. Secondly, the study has made a significant contribution by trying to look at the relationship for the same income group as they share some characteristics for a more robust result.

The paper proceeds as follows: First, the study provides an introduction in section 1, followed by a brief review of related research contained in section 2. The study further presents the method of data analysis in Section 3 as the estimated results are contained in Section 4. Finally, section 5 displayed the policy implication and the conclusion of the study.

2. LITERATURE REVIEW

The relationship connecting energy consumption with economic growth has significant implication both from the empirical, theoretical and policy point of view. For instance, a unidirectional causality running from economic growth to energy consumption entails that energy consumption is determined by economic growth; therefore, energy conservation policies can be actualized with little or no negative effect on economic growth [8]. Likewise, a unidirectional causality running from energy consumption to economic growth signifies that economic growth rely upon energy consumption and as a result, a watchful energy policy is recommended as any decrease in energy consumption might have a negative impact on economic growth.

Related studies on the relationship between energy consumption and economic growth followed the original work of [3] for the United States, and later expanded to involve industrialized nations such as: Japan, Greece, France, and Germany among others. Still, empirical

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findings for energy-growth nexus appear to be contradicting [9]. The absence of general agreement may be generally because of the distinctions in the stages of development for different nations studied or the dissimilarities in the data as well as the technique employed [10].

In the successive studies, while some studies utilized the time series approach, other studies employed the panel data approach. Within the time series approach, cointegration and Vector Error Correction Model (VECM) method were used to justify the relationship between energy consumption and economic growth. For instance, [11] examined the causality between energy consumption and economic growth for Tunisia and maintained causality running from energy consumption to economic growth. Similarly, [12] analyze energy consumption with economic growth in Vietnam and established causality running from energy consumption to economic growth. Contrary to this finding, [13] revealed causality running from economic growth to energy consumption. Furthermore, the feedback hypothesis was proved for Canada using cointegration and VECM in the study of [14]. Similarly, [15] utilized VECM and established a feedback relationship between electricity consumption and economic growth in Turkey. Finally, [13] suggest no causality among economic growth and energy consumption for Singapore, Malaysia and the Philippines.

Employing the Bounds testing to cointegration within the Autoregressive Distributed Lag (ARDL) framework, [16] investigated energy dependence for two lower-middle income countries (Ghana and Cote D' Ivoire) and two middle-upper income countries (Brazil and Uruguay). The empirical findings disclosed a unidirectional causality from energy consumption to economic growth for Brazil and Uruguay as well as a unidirectional causality from economic growth to energy consumption for Ghana and Cote D' Ivoire. Contrary to these findings, [17] established bidirectional causality for Ghana, Gambia and Senegal within the ARDL framework. Lastly, [18] looked at energy consumption and GDP for Turkey. They revealed no causality among energy consumption and economic growth.

Within the panel data approach, panel cointegration and causality tests were employed in the relationship among energy consumption and economic growth. [19] take the case of Economic Community of West African States (ECOWAS) countries during the period 1980-2008 and described a long run causal relationship running from energy consumption to economic growth as well as, a short run causality running from economic growth to energy consumption. Furthermore, [20] maintained causality running from economic growth to energy consumption for the Gulf Co-operation Countries by using panel cointegration and causality tests. On the account of SSA countries, a contrary view of feedback between energy consumption and economic growth was maintained for 14 SSA countries [21].

Utilizing panel VECM within the panel data framework, [22] proved causality running from energy consumption to economic growth for Indonesia, Argentina, Kuwait, Nigeria, Malaysia, Saudi Arabia and Venezuela, as well as a feedback relationship for Japan, Sweden, Australia, Norway, UK, and USA. Also [10] revealed the existence of bidirectional causality between energy consumption and economic growth for China. Similarly, [23] established a feedback relationship among natural gas energy consumption and economic growth.

3. METHOD OF DATA ANALYSIS

3.1 Framework

In this paper, we propose the conventional Cobb-Douglas production function suggested in the framework of [24] and employed by [25]. In the model, output is given by:

$$y_t = A_t k_{t,}^{\alpha} \qquad \alpha > 0 \tag{1}$$

where:

A represents the stock of technology
k_t is the capital at time t
α is the share of profit.

In the Solow Model, it is assumed that technology evolution is given by:

$$\psi_t = A_0 e^{gt} \tag{2}$$

where:

ψ_t is the aggregate technology A_t
A_0 represents the initial stock of knowledge
t is the time period
g represents the technological progress rate.

In this regard, it is assumed that the time variant technology is given by energy, hence

$$\psi_t = f(ENG) \tag{3}$$

where:

ENG represents energy consumption. Therefore, the effect if *ENG* on Total Factor Productivity is explained when *ENG* is used as a shift variable into the production function. The rationale behind adding the shift variable was developed by Rao (2010), hence

$$\psi_t = A_0 e^{gt} ENG_t^{\rho} \tag{4}$$

and

$$\psi_t = (A_0 e^{gt} ENG_t^{\rho}) k_t^{\alpha} \tag{5}$$

Therefore Equation 6 is obtained by transforming Equation 5 into natural logarithm and will be used to estimate long run relationship once cointegration is established among the variables.

$$LMANF_{it} = \gamma_0 + \gamma_1 LENG_{it} + \gamma_2 LCAP_{it} + \gamma_3 LLAB_{it} + \varepsilon_{it} \tag{6}$$

where, *LMANF* is the manufacturing industry performance. The independent variables that influence *LMANF* include the level of energy consumption (*LENG)* capital *(LCAP)* and labour *(LLAB)* inputs, γ_0 is the intercept, γ_1, γ_2 and γ_3 represents the parameters estimated, t represents the time series, i represents the entity data for each country in the model and ε is the error term.

3.2 Data

This study utilized annual data from panel of seven low-income SSA countries (Benin, Congo DR, Cameroon, Kenya, Mozambique, Togo and Tanzania) for the period 1990-2012. The choice of these countries and the time period was based on the availability of data for all the variables in the study. Manufacturing industry performance *(LMANF)* is measured by manufacturing value added (constant USD) while, energy consumption *(LENG)* is measured by energy use (kg of oil equivalent per USD10,000 GDP, constant 2011 PPP). Capital *(LCAP)* is proxy by gross capital formation (constant USD) as labour *(LLAB)* is proxy by population growth (annual percentage). The data for all the variables are sourced from World Development Indicators.

3.3 Estimation Procedure

The first prerequisite condition to investigate the existence of panel cointegration is to determine the stationarity property of the data. This paper therefore, utilized the panel unit root test advanced by [26] based on the Dickey-Fuller procedure. Reference [26] proposed a panel unit root by integrating information from the cross-section dimension with that from the time series dimension. The advantage of this test is that it has superior test power in analyzing the long run relationship in panel data. The test commences by specifying separate ADF regression for each cross-section with individual effects and no time trend:

$$\Delta y_{it} = \alpha_i + \rho_i y_{i,t1} + \sum_{j=1}^{p_1} \beta_{ij} \Delta y_{i,tj} + \varepsilon_{it} \qquad (7)$$

where $i = 1, \ldots, 4$ and $t = 1995, \ldots, 2012$
Following the separate estimation of ADF regressions, the average of the t-statistics for p_1 from the individual ADF regressions is given by:

$$\overline{t}_{NT} = \frac{1}{N} \sum_{i=1}^{N} t_{iT}(p_i \beta_i) \qquad (8)$$

Small number of N and T can be accommodated by the t-bar test. The t-bar test also converges to standard normal distribution as N and $T \to \infty$.

3.4 Panel Cointegration Tests

Given the establishment of a panel unit root, the next issue is to investigate whether cointegration exist among *MANF* and the independent variables. This paper used the [27], [28] test to investigate cointegration among the variables. Pedroni proposed the following regression:

$$y_{i,t} = \alpha_i + \delta_i t + \beta_{1i} x_{1i,t} + \beta_{2i} x_{2i,t} + \ldots\ldots + \beta_{Ki} x_{Ki,t} + e_{i,t} \qquad (9)$$

Where;

K	represents the number of regressors
t	is the observation over time
i	is the cross-sectional unit in the panel
α_i	represents the intercepts, and
$\delta_i t$	represents specific time effect

References [27], [28] make use of seven tests for panel cointegration consisting of the heterogeneous panel test which is based on poling residuals within the dimension in the panel, and the heterogeneous group mean panel test which is based on pooling residuals between the dimensions in the panel. The seven tests are computed in Equation (10) to (16):

Panel v- statistics:

$$z_\upsilon = \left(\sum_{i=1}^{N} \sum_{i=1}^{T} \hat{L}_{11i}^{-2} \hat{e}_{it-1}{}^2 \right)^{-1} \qquad (10)$$

Panel ρ-statistics:

$$z_\rho = \left(\sum_{i=1}^{N} \sum_{i=1}^{T} \hat{L}_{11i}^{-2} \hat{e}_{it-1}{}^2 \right)^{-1} \sum_{i=1}^{N} \sum_{i=1}^{N} \hat{L}_{11i}^{-2} \left(\hat{e}_{it-1} \Delta \hat{e}_{it} - \hat{\lambda}_i \right) \qquad (11)$$

Panel PP-statistics:

$$z_t = \left(\hat{\sigma}^2 \sum_{i=1}^{N} \sum_{i=1}^{T} \hat{L}_{11i}^{-2} \hat{e}_{it-1}^2 \right)^{-1/2} \sum_{i=1}^{N} \sum_{i=1}^{N} \hat{L}_{11i}^{-2} \left(\hat{e}_{it-1} \Delta \hat{e}_{it} - \hat{\lambda}_i \right) \qquad (12)$$

Panel ADF-statistics

$$z_t{}^* = \left(\hat{S}^{*2} \sum_{i=1}^{N} \sum_{i=1}^{T} \hat{L}_{11i}^{-2} \hat{e}_{it-1}^{*2} \right)^{-1/2} \sum_{i=1}^{N} \sum_{i=1}^{N} \hat{L}_{11i}^{-2} \hat{e}_{it-1}^{*} \Delta \hat{e}_{it}^{*} \qquad (13)$$

Group ρ-statistics:

$$\tilde{Z}_\rho = \sum_{i=1}^{N} \left(\sum_{t=1}^{T} \hat{e}_{it-1}^2 \right)^{-1} \sum_{t=1}^{T} \left(\hat{e}_{it-1} \Delta \hat{e}_{it} - \hat{\lambda}_i \right) \qquad (14)$$

Group PP-statistics:

$$\tilde{Z}_t = \sum_{i=1}^{N} \left(\hat{\sigma}^2 \sum_{t=1}^{T} \hat{e}_{it-1}^2 \right)^{-1/2} \sum_{t=1}^{T} \left(\hat{e}_{it-1} \Delta \hat{e}_{it} - \hat{\lambda}_i \right) \qquad (15)$$

Group ADF-statistics:

$$\tilde{Z}_t * = \sum_{i=1}^{N} \left(\sum_{t=1}^{T} \hat{s}_i^{\,2} \hat{e}_{it-1}^{*2} \right)^{-1/2} \sum_{t=1}^{T} \left(\hat{e}_{it-1}^{*} \Delta \hat{e}_{it}^{*} \right) \tag{16}$$

where:

$\hat{e}_{it}$	is the estimated residual
$\hat{L}_{11i}^{2}$	is the estimated long-run covariance matrix for $\Delta \hat{e}_{it}$
$\hat{s}_i^2 (\hat{s}_i^{*2})$	are the long-run variances for individual *i*
$\hat{\sigma}_i^2$	are the contemporaneous variances for individual, *i*

All the seven tests are distributed as being standard normal asymptotically. This needs a standardisation based on the moments of the underlying Brownian motion function.

3.5 Coefficients Estimation

Following the establishment of cointegration among the variables, next is to estimate the long run coefficient by adopting the Fully Modified Ordinary Least Square (FMOLS) procedure. One of the advantages of FMOLS is that it handled serial correlation and non-exogeneity in the model. Also, the model provides efficient and consistent estimation of cointegrating vectors. The cointegrated system of panel data starts by OLS in Equation (17) as follows:

$$y_{it} = \alpha_i + x_{it}^{'} \beta + e_{it} \tag{17}$$

$$x_{it} = x_{i,t1} + \varepsilon_{it}$$

where

$\xi_{it} = [e_{it,} \varepsilon_{it}^{'}]$	represent stationary with covariance matrix Ω_i
β	will be consistent if error process satisfy y_{it} and x_{it}

To eliminate the order bias caused by endogenous regressors, [29], [30] follows the [31] approach in correcting the OLS estimators within the panel data context and allowing for short run dynamics heterogeneity. Thus, Equation (18) estimates the Pedroni's FMOLS as:

$$\hat{\beta}_{FM} = \left(\sum_{i=1}^{N} \hat{\Omega}_{221}^{2} \sum_{T=1}^{T} (x_{it} \hat{x}_t)^2 \right)^{1} \sum_{i=1}^{N} \hat{\Omega}_{11i}^{1} \hat{\Omega}_{22i}^{1} \left(\sum_{t=1}^{T} (x_{it} \overline{x}_t) e_{it} T \hat{\gamma}_i \right) \tag{18}$$

$$\hat{e}_{it} = e_{it} \hat{\Omega}_{22i}^{1} \hat{\Omega}_{21i,}$$

$$\hat{\gamma}_1 = \hat{\Gamma}_{21i} + \hat{\Omega}_{21i}^{0} \hat{\Omega}_{22i}^{1} \hat{\Omega}_{21i} (\hat{\Gamma}_{22i} + \hat{\Omega}_{22i}^{0})$$

where

$\Omega_{\mathrm{i}} = \Omega_{\mathrm{i}}^{0} + \Gamma_{\mathrm{i}} + \Gamma_{\mathrm{i}}$ is the decomposed covariance matrix

Ω_{i}^{0}	is the contemporaneous covariance matrix
Γ_i	is a weighted sum of auto covariances.

4. ESTIMATION RESULTS

The IPS panel unit root test presented in Table 1 indicated that all the variables are non-stationary at level using constant and constant plus time trend. Therefore, we fail to reject the null hypothesis of a panel unit root in the level of the series. Thus, it was concluded that the variables are non-stationary with or without time trend at level.

However, taking the first difference of the series in constant and constant plus time trend, the result showed that the null hypothesis of unit root is rejected for all the series at 5% level of significance. Hence, it is worth concluding that there was enough evidence that all the series are integrated of order one, *I(1)* based on the IPS test.

From the IPS unit root test result, it is possible to proceed with the estimation of the panel cointegration advanced by [27], [28] to enable us find out whether long run relationship exists among the variables. Table 2 presented the panel cointegration test result.

Table 1. Panel unit root test result.

Variables	Level		First Difference	
	Constant	Constant + Trend	Constant	Constant + Trend
LMANF	-0.999	0.309	-7.092*	-6.604*
	(0.159)	(0.621)	(0.000)	(0.000)
LENG	1.477	1.262	-4.012*	-6.013*
	(0.930)	(0.897)	(0.000)	(0.000)
LCAP	-0.263	1.012	-7.936*	-5.070*
	(0.396)	(0.844)	(0.000)	(0.000)
LLAB	0.149	0.270	-1.788*	-3.156*
	(0.559)	(0.607)	(0.048)	(0.001)

*Note: * indicates 5% level of significance. Figure in parenthesis represents probability value.*

Table 2. The Pedroni panel cointegration test.

Variables	Coefficients	Prob.
Panel υ-statistics	-0.460	0.677
Panel rho-statistics	-0.729	0.232
Panel PP-statistics	-4.609	0.000*
Panel ADF-statistics	-2.980	0.001*
Group rho-statistics	1.493	0.932
Group PP-statistics	-1.913	0.027*
Group ADF-statistics	-1.597	0.055**

*Note: *, ** indicates 5% and 10% level of significance, respectively.*

Table 3. FMOLS regression.

Variables	Homogenous Variance		Heterogeneous Variance	
	Coefficient	T-Statistics	Coefficient	T-Statistics
Estimated long run coefficient				
LENG	0.050*	2.554	0.050*	2.037
	(0.011)		(0.039)	
LCAP	0.197*	5.322	0.197*	4.940
	(0.000)		(0.000)	
LLAB	2.478	3.475	2.478	3.519
	(0.150)		(0.156)	

Note: * indicates 5% level of significance. Figures in parenthesis represent probability value.

From Table 2, it was revealed that three out of the seven statistics reject the null hypothesis of no cointegration at 5% significance level for the Panel *PP*-statistics, Panel *ADF*-statistics and Group *PP*-statistics while in the Group *ADF*-statistics, the null hypothesis of no cointegration is rejected at 10% significance level. Therefore, four out of the seven statistics reject the null hypothesis of no cointegration. This indicated that the independent variables possess cointegration in the long run for the seven sampled low-income SSA countries with respect to *LMANF*. Having found cointegration among the variables, next is to estimate the long run coefficient through the FMOLS procedure. Table 3 presents the FMOLS regression.

Table 3 presents the long run parameter estimates of manufacturing industry performance equation in terms of energy consumption, capital formation and labour. The method of estimation utilizes the homogenous and heterogeneous estimation of the FMOLS. All the regressors are found to be statistically significant at 5% level of significance. Energy consumption and capital formation are found to have positive effect on manufacturing industry performance while labour was found insignificant in explaining manufacturing industry performance.

According to the homogenous and heterogeneous variance structure result displayed in Table 3, one percent increase in energy consumption and capital formation will lead manufacturing industry performance to increase by 5% and 19.7%, respectively. Therefore, it worth concluding that the growths in energy consumption and capital have positive effect on the performance of the manufacturing sector in the panel of seven low-income SSA countries. This implied that higher level of energy consumption and capital formation means higher level of manufacturing industry performance. Thus, enhancing efficient energy supply and access to capital in the seven low-income SSA countries will enhance the performance of the manufacturing sector. This result was consistent with [32]-[36]. For instance, Narayan and Smyth maintained that energy consumption and capital have a positive effect on real output. Similarly, Kumar and Kumar take the case of Kenya and South Africa and maintained that increase in energy consumption result in growth of output.

5. POLICY IMPLICATION AND CONCLUSION

This paper examines the effect of energy consumption, capital and labour on manufacturing industry performance for seven low-income SSA countries within the multivariate framework. The study was motivated owing to the fact that most of the previous studies lay more emphasis on the energy-growth nexus and there is a need to look into the manufacturing sector performance in isolation as increase in the manufacturing industry performance will in general lead to an increase in GDP. Also, the issues of over reliance on importation of goods in SSA have raise interest on the performance of manufacturing sector in SSA. The IPS unit root confirms the stationarity of all the variables before performing the cointegration test. Following the confirmation of the stationary of the variables, the panel cointegration approach is used in investigating the long run cointegration among the variable. The result obtained shows the presence of cointegration among the variables. The coefficients of the long run show a positive significant relationship between manufacturing industry performance and energy consumption as well as between manufacturing industry performance and capital. However, the result turns to be insignificant between manufacturing industry performance and labour. Generally, the paper demonstrates statistical evidence that energy consumption and capital formation are the determinants of manufacturing industry performance for the low-income SSA countries.

From the policy view point, the result suggests that energy policy is important in enhancing manufacturing industry performance. This is owing to the fact that energy consumption stimulates the performance of the manufacturing sector. Therefore, the need to implements policies that will enhance energy consumption cannot be over emphasize. Consequently, policy makers should implement policies that will reduce the problems of promoting sustainable energy in SSA such as; the problem of monopoly structures in the energy sector and the problem of capital requirement to fund sustainable energy scheme among others.

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