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ESTIMATING THE DETERMINANTS OF ENERGY CONSUMPTION IN MUTLISECTORAL AFRICAN ECONOMIES: EVIDENCE FROM PANEL METHODS EFFICIENT TO HETEROGENEITY AND CROSS-SECTIONAL RELIANCE

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ABSTRACT

This present study uses a panel of 24 countries over the period of 1990-2015 to analyze proposed determinants of energy consumption in Africa. The panel is categorized into LI, LMI and UMI African economies. Applying econometric tests and DCCE estimator through a specified DHPD model, issues of heterogeneity and cross-sectional reliance were considered. Our established findings indicated that, GDP, OP, URB, and POPg are potential drivers of EC when capital stock and labor are used as control variables. Further, with the exception of URB-EC, POPg-EC, POPg-GDP, and POPg-URB nexus whose direction of causality were common across country groups, variations occurred for the causalities amid GDP-EC, OP-EC, OP-GDP and URB-GDP nexus for the different income level groups. We therefore conclude that, factors unique to the various country groups in terms of income levels influence the causal affiliations between analyzed variables. Policy recommendation are briefly discussed.

Keywords: Energy consumption, heterogeneity, cross-sectional reliance, Africa

Nomenclature

Abbreviations	
GDP	Gross Domestic Product
EC	Energy Consumption
OP	Oil Price
DCCE	Dynamic Common Correlated Effect
DHPD	Dynamic Heterogeneous Panel Data
L	Labor
K	Capital stock
POPg	Population growth
URB	Urbanization
UMI	Upper-middle income
LMI	Lower-middle income
LI	Low income
RMSE	Root Mean Square

1. INTRODUCTION

Energy has become the life force of all up-to-date economies. It drives the helms of economic growth and a significant factor in the production of almost all goods and services in addition to capital and labor. Due to rapid economic development, energy consumption is rising especially in developing countries of which countries in Africa are not exceptional. Economies cannot develop without energy consumption. In fact, the use of energy promotes economic opportunities, reduces level of travel costs and upgrades the industrial sector, leading to modernization of the economy [1]. However, compared with other regions, the continents' energy consumption remains low in terms of energy substances. For example, in 2009 alone, energy consumption in terms of electricity in Europe was 11 times that in SSA, despite the larger population of SSA countries [2]. Energy use has increased capital accumulation in Africa, leading to rapid economic growth, especially since 2000. The United Nations (2011) [3] emphasizes that Africa is thriving and its demographic structure is changing rapidly, since its population is anticipated to reach 2.3 billion by 2050 (up from 1 billion in 2010). Taking advantage of this large population, its productive sectors will require supplementary inputs such as energy. Since then, as energy use upsurges, Africa can use its capital stock and labor to accelerate its economic growth. Naturally, one can therefore expect Africa to significantly increase its energy consumption in the short and medium terms as its economies modernize, urbanization gains and population changes.

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Understanding the relationship between Africa's energy consumption and its determinants is therefore essential for economists and policy makers.

Due to the growing relevance of this topic on energy consumption, several empirical studies have been conducted centering on the global perspective with majority focusing on energy consumption and one factor for instance economic growth (see example; [4,5]). Though generating sustained energy consumption in Africa remains one of the most pressing challenges in global development, not much attention is known about Africa-specific determinants of energy consumption. Nonetheless, researches on energy consumption and more influence factors are rare on the African continent.

Different from previous studies conducted in Africa, this present study includes energy price in terms of oil price, urbanization and population density in addition to economic growth by using labor force and capital stock as intermittent variables for a heterogeneous panel of 24 African economies over the period of 1990-2015 within a multivariate framework. It is therefore expected that, the study will add-up to literature in the following ways;

i. To the best of our knowledge, though emphasis is beginning to be centered on energy use and its determinants in Africa, no studies have taken into account issues of heterogeneity and cross-sectional reliance. This study thus employs heterogeneous and cross-sectional correlation approaches which incapacitates the shortcomings of conventional panel techniques to ensure the rationality of parameter estimation and consistency of the causality test.

ii. Contributively, this study also resolves the issue of "lump-together" in using panel data; authors therefore categorize the panel data into three sub-groups based on variations in the income levels of African countries (Upper-middle income, Lower-middle income and Low income) which most studies in this region paid less attention to.

The remainder of the paper is categorized as follows: Section 2 outlines the model specification and data. Section 3 reports the empirical results from the study and Section 4 concludes the paper.

2. MODEL SPECIFICATION AND DATA

In accordance to empirical literature concerning energy economics, this current study examines the determinants of energy consumption by slotting in economic growth, population density, oil price, and urbanization with capital stock and labor force as control variables. Thus, the proposed model for this study which appears to be in consonant with literature takes the form;

$$\mathrm{EC} = \mathrm{f}(\mathrm{GDP}, \mathrm{OP}, \mathrm{URB}, \mathrm{POPg}, \mathrm{L}, \mathrm{K}) \tag{1}$$

where EC represents energy consumption per capita (in kg equivalent), GDP represents economic growth per capita (constant 2010 US$), OP is price of energy in terms of oil price (USD per barrel), URB denotes urbanization (urban population as the share of total population), POPg is the population growth (annual percentage), L is labor force (total) and K represents capital stock (gross capital formation (current US$).

Due to the issue of heteroskedasticity, all variables included in the proposed model are transformed into natural logarithm. Thus, the log-linear model used to examine the effect of explanatory variables on energy use in a panel case is formulated as;

$$\begin{aligned}\mathrm{lnEC}_{\mathrm{i,t}} = \beta_{\mathrm{o}} + \beta_1 \mathrm{lnGDP}_{\mathrm{i,t}} + \beta_2 \mathrm{lnOP}_{\mathrm{i,t}} + \beta_3 \mathrm{lnURB}_{\mathrm{i,t}} \\ + \beta_4 \mathrm{lnPOPg}_{\mathrm{i,t}} + \beta_5 \mathrm{lnL}_{\mathrm{i,t}} + \beta_6 \mathrm{lnK}_{\mathrm{i,t}} \\ + \varepsilon_{\mathrm{i,t}}\end{aligned} \tag{2}$$

where i is individual country at time t and $\varepsilon_{\mathrm{i,t}}$ is the cross-sectional error terms.

The data were obtained from WDI (2016) [6] data base and OPEC average annual crude oil prices. Though crude oil price is usually in US dollars, for the purpose of this study, the US dollar for oil prices was converted to domestic currencies of the various countries involved in the study using average annual official exchange rate provided by WDI. The sample of countries selected for the study were categorized into three main sub-panels. Relying on the World Bank and lending group classification in 2017, these 24 African countries were classified into Upper-middle income, Lower-middle income and Low-Income African countries (henceforth UMI, LMI and LI respectively).

2.1 Econometric tests

Issues of homogeneity and cross-sectional reliance among variables within panel time series data depict the significance for further selection of econometric tests to be employed in the analysis for instance unit root and cointegration tests. We therefore first test for cross-sectional affiliations among the series using $\mathrm{CD_{LM}}$ test by [7] and also test for homogeneity with adjusted delta tilde ($\tilde{\Delta}_{\mathrm{adj}}$) procedure of [8]. Considering potential cross-sectional affiliations and heterogeneity, we then analyzed the integration levels of the variables with CIPS and CADF unit root tests of [9]. Later, we investigated the existence of long-run liaison among variables with both [10] and [11] bootstrap panel cointegration tests. We then estimated the long-run cointegrating coefficients by employing a recently developed estimator (DCCE estimator) by [12] through a DHPD model, which is specified as:[1]

$$\ln EC_{i,t} = \phi_i \ln EC_{i,t-1} + \alpha \ln GDP_{i,t} + \beta \ln OP_{i,t} + \gamma \ln URB_{i,t} + \delta \ln POPg_{i,t} + \sum_{j=1}^{2} \theta_j' Z_{i,t} + \sum_{\ell=0}^{\rho_T} \delta_{i,\ell}' \bar{m}_{t-\ell} + \varepsilon_{i,t} \quad (3)$$

where $\alpha, \beta, \gamma, \text{and } \delta$ captures the effect of economic growth(GDP), price of oil, urbanization and population growth on energy use whilst ϕ_i measures the changes in energy use from the short-term to the long-term and θ_j captures the effect of the control variables on energy consumption (labor force and capital stock), $\bar{m}_t = (\overline{\ln EC_{i,t}}, \overline{\ln EC_{i,t-1}}, \overline{\ln GDP_{i,t}}, \overline{\ln OP_{i,t}}, \overline{\ln URB_{i,t}}, \overline{\ln POPg_{i,t}}, \overline{Z_{i,t}})$ represents the cross-sectional means, ρ_T on the other hand is the number of lags assumed to be equal across all units and is given by the relation $\left(\rho_T = \sqrt[3]{T}\right)$.

Finally, we tested for the causalities amid core variables (energy use, population density, urbanization, and oil price) using panel causality test by [13] which has the ability to produce robust results in the presence of cross-sectional reliance and heterogeneity.

3. RESULTS AND DISCUSSIONS

3.1 Homogeneity and Cross-sectional reliance test

Results from both the homogeneity test and CD_{LM} test are presented in Table 1. The homogeneity test with respect to $\tilde{\Delta}_{adj}$ (adjusted delta_tilde) and its probability values of for all country groups gives a strong evidence of rejecting the null hypothesis of homogeneity. This therefore implies that, there exist slope heterogeneity within the proposed model for all country groups. Likewise, outcome of the CD_{LM} test uniformly rejects the null hypothesis of cross-sectional independence with strong evidence at 1% significance level also across all country groups. The evidence of cross-sectional dependence from the policy viewpoint means variations that occur in an interested variable (for example energy use) in specific country is likely to affect other countries in the same region. In other words, this further insinuates that there exist strong economic ties among countries within the various country groups in Africa.

Table 1 Results from cross-sectional dependence and Homogeneity test[2]

Groups	Test	Statistic	P-value
UMI	$\tilde{\Delta}$ adj.	17.46[a]	0.00
	CD_{LM}	18.72[a]	0.00
LMI	$\tilde{\Delta}$ adj.	45.38[a]	0.00
	CD_{LM}	59.85[a]	0.00
LI	$\tilde{\Delta}$ adj.	25.33[a]	0.00
	CD_{LM}	53.84[a]	0.00

NOTE: a represents significance level at 1%

3.2 Panel unit root test

Results from both CADF and CIPS unit root tests using estimation based on constant with trends at levels and first differences respectively are presented in **Table** 4. Both tests for all country groups, fail to reject the null hypothesis of series having unit root at levels. This finding gives a strong indication that all variables are not stationary at levels but rather become stationary in the first difference at 1% level of significance. Thus we draw a conclusion that all series in the presence of cross-sectional correlations and heterogeneity are non-stationary and follow the same order of integration (I(1)) when differenced.

Table 2 Results from CADF and CIPS panel unit root tests

Variable	CADF		CIPS		Decision
UMI	LEVELS	Δ	LEVEL	Δ	I(1)
EC	-1.97	-3.15[a]	-2.25	-4.51[a]	I(1)
GDP	-2.23	-3.19[a]	-2.28	-4.65[a]	I(1)
POPg	-1.91	-5.30[a]	-0.58	-2.88[c]	I(1)
URB	-1.10	-2.99[a]	-1.46	-4.24[a]	I(1)
K	-2.52	-3.26[a]	-2.53	-4.86[a]	I(1)
LF	-2.25	-3.29[a]	-1.54	-4.15[a]	I(1)
OP	-2.13	-3.49[a]	-2.45	-3.58[a]	I(1)
LMI					
EC	-2.12	-3.27[a]	-1.84	-4.22[a]	I(1)
GDP	-1.26	-3.25[a]	-1.33	-3.91[a]	I(1)
POPg	-1.53	-5.67[a]	-1.81	-2.71 [b]	I(1)
URB	-1.49	-2.78[b]	-1.76	-3.40 [a]	I(1)
K	-2.53	-3.79[a]	-1.32	-4.59[a]	I(1)
LF	-2.45	-2.91[a]	-1.59	-2.78[b]	I(1)
OP	-1.45	-2.93[a]	-1.47	-3.78[a]	I(1)
LI					
EC	-2.03	-3.51[a]	-1.89	-4.46[a]	I(1)
GDP	-1.57	-2.96[a]	-1.63	-4.24[a]	I(1)

[1] In estimating the model in Eq. (3) using the DCCE estimator, the lagged dependent variable is not strictly exogenous, thereby making the inconsistent. Chudik and Pesaran (2015) therefore showed that the estimator gains consistency if a sufficient number of lags of cross-section averages are added to the model.

POPg	-2.17	-5.02[a]	-1.28	-4.92[a]	I(1)
URB	-1.54	-3.24[a]	-1.76	-4.32[a]	I(1)
K	-2.54	-3.72[a]	-1.45	-4.91[a]	I(1)
LF	-2.31	-2.23[a]	-1.49	-3.55[a]	I(1)
OP	-2.50	-3.19[a]	-1.16	-3.83[a]	I(1)

NOTE: a represents significance level at 1%, b represents significance at 5% level and c means significance at 10% level.

3.3 Panel cointegration test

Summary of findings from the W-E bootstrap cointegration test are further reported in Table 4. The outcome with EC as the dependent variable shows that, all the variables with respect to their robust p-values for all country groups are cointegrated since the null hypothesis of no cointegration is rejected at 1% and 5% significant levels respectively for the various statistics. Findings based on the robust p-values give a stronger proof of cointegration amid analyzed variables. We therefore draw a conclusion that, the variables being analyzed have a long-run relationship.

Table 4 Results from Westerlund-Edgerton bootstrap cointegration test

Group	G_τ		G_α		P_τ		P_α	
	Value	R	Value	R	Value	R	Val.	R
UMI	-4.94[a]	0.00	-11.87[a]	0.01	-10.15[a]	0.00	-10.43[b]	0.02
LMI	-4.82[a]	0.00	-8.01[b]	0.04	-15.61[a]	0.00	-18.33[b]	0.02
LI	-4.88[a]	0.00	-9.40[a]	0.00	-11.45[a]	0.00	-20.33[a]	0.00

NOTE: a represent significance level at 1% and 5% respectively.

3.4 Coefficient analysis

Once the long-term relationship has been confirmed amongst analyzed variables, it is of much importance to empirically study the estimate of their respective coefficients. Results based on the DCCE estimator using the DHDP model are outlined for various country groups in **Table** 5.

Table 5 Estimation results for the three sub-panels

Variables	LI	LMI	UMI
L.EC	0.002[c]	0.011[c]	0.072[b]
GPD	0.535[a]	0.497[a]	0.425[a]
POPg	0.354[a]	0.533[a]	0.824[a]
URB	0.908[a]	0.787[a]	0.658[a]
K	0.109[a]	0.167[a]	0.212[a]
L	0.245[a]	0.811[a]	0.803[a]
OP	0.279[a]	0.293[a]	0.210[a]
Fstat	3.080[a]	2.710[a]	2.940[a]
R-squared	0.850	0.830	0.810
Root MSE	0.070	0.010	0.030

NOTE: a, b and c represent significance level at 1%, 5% and 10% respectively.

The coefficient of the lagged energy consumption (L.EC) for LI, LMI and UMI African countries are positive and statistically significant at 10% and 5% levels respectively. The respective lagged values imply that for LI African nations, any deviation from the long-run equilibrium between the variables is corrected by 0.2% whilst that of LMI African economies it is corrected by 1.1% and changes of energy use from short-run to the long-run for UMI African nations is 7.2%. All the coefficients with respect to the analyzed variables are positive and statistically significant at 1%. Thus, given that the variables are in natural logarithm transforms, their respective parameter estimates can be explained as elasticities. Generally, results base on the parameter estimates shows that there is a robust long-run liaison between analyzed variables. Finding in the context of LI African nations suggest that, when K and L are being controlled for, 1% upsurge in GDP, POPg, URB and OP will trigger EC respectively to rise by 0.535%, 0.354%, 0.908% and 0.279%. Hence GDP is the second most contributing factor to energy use after URB followed by POPg in LI African nations. There are further variations in results when LMI and UMI are considered. For instance, in LMI African economies, 1% surge of GDP, POPg, URB and OP when K and L are controlled for increases EC by 0.497%, 0.533%, 0.787% and 0.293% respectively. As much as UMI African states are concerned, a percentage upswing of GDP, POPg, URB and OP when K and L are considered as intermittent variables increase EC correspondingly by 0.425%, 0.824%, 0.658% and 0.210%. Capital stock and labor force employed as control variables were identified to respond to deviations in the long-run equilibrium with significant effect on energy use for all country groups though labor force is found to be highly significant compared to capital stock from one country group to the other. The inclusion of labor and capital stock is of great essence because they reduce the problem of biasness and complementarities in omitted variables. The essence of these variables as elasticities in the long-term implies that, both labor and capital stock are very significant in explaining the changes in energy use. Overall the estimated DHPD model for each panel portrays a good sign of robustness. This is due to the fact that, firstly F-test statistic for each panel is statistically significant meaning data for each case is able to fit the model well. Additionally, the R^2 values for each given panel are respectively high indicating major variabilities in the response variable (energy consumption) are explained by the predictor variables (LI=>R^2=85.0%, LMI=>R^2=83.0%, UMI=>R^2=81.0%). Finally, the RMSE values for the estimated model for each panel are less than 0.08 (Hair et al, 2017) which implies that the model has a good predictive power in predicting the response variable.

3.5 Panel causality test

Documentation by numerous researches, both previous and current years indicate that, the affirmation of long-term relationship further implies the existence of causalities among analyzed variables. The long-run estimates from the DCCE estimator with no doubt gives inferences but not capable of revealing the direction of causalities amid variables. Nonetheless, it is therefore of interest for authors to pin down to the information concerning the direction of causal relationships among core variables which includes EC, GDP, POPg, URB and OP. The study therefore adopted D-H Granger causality test due the presence of cross-sectional correlations and heterogeneity. Summarily, the findings based on the D-H Granger causality test regarding African countries with different income levels are recounted in **Table** 6[3].

Table 6 Summary results from D-H Granger causality test

LI	LMI	UMI
GDP→EC	GDP↔EC	GDP↔EC
OP↔EC	OP→EC	OP→EC
URB↔EC	URB↔EC	URB↔EC
POPg→EC	POPg→EC	POPg→EC
OP↔GDP	OP↔GDP	OP→GDP
URB↔GDP	URB↔GDP	URB→GDP
POPg↔GDP	POPg↔GDP	POPg↔GDP
POPg↔URB	POPg↔URB	POPg↔URB

Note: ↔ represents two-way causal relationship (feedback hypothesis), → denotes one-way causal effect

There is enough witness to deduce that, common to all groups in terms of different income levels, there exist a bilateral liaison amid URB and EC, POPg and GDP, POPg and URB and a unilateral causation from POPg to EC across all panels. In the context of variations, the findings per the causal relationships supports that a one-sided connection from GDP to EC in LI African states whereas a feedback hypothesis is confirmed amid GDP and EC in the case of LMI and UMI African nations. Concerning OP-EC nexus, a consensual liaison is observed in LI African economies though one-way affiliation runs from OP to EC in both LMI and UMI African countries. Conversely, for both LI and LMI African nations a bilateral connectedness is flanked by OP and GDP whereas on the side of UMI African states a single-directional causation extends from OP to GDP. URB and GDP on the other hand are characterized by a two-sided relationship in both LI and LMI countries in Africa whilst UMI African nations are defined with one-sided connection running from URB to GDP. Interestingly the study identified no causal affiliations amid OP and URB, as well as OP and POPg for all country groups. Summarily the outcomes concerning the causal relationships are in consonant with the bulk of literature pertaining the topic under discussion (see example; [14, 15])

4. CONCLUSION

This study investigated the determinants of energy consumption for a panel of 24 heterogeneous African economies over the period 1990-2015. The sample of African economies were decomposed into three sub-panels namely; Low, Lower-middle and Upper-middle income countries. The main goal for these sub-panels is to observe whether factors unique to the used country groups influence the causal liaisons amid analyzed variables. The study identified heterogeneity, cross-sectional dependencies, same order of integration and long-run relationship amid variables which needs to be estimated. Thus, using DCCE estimator through DHPD model, GDP, URB, POPg, and OP were evidence to have positive and statistically significant effect on energy use for all country groups when capital stock and labor were employed as intermittent variables. Direction of causalities were finally investigated using the D-H Granger causality test. Though some common causalities were identified across all panels, relying on variabilities;

(i) A one-sided link from GDP to EC in LI African states is evidenced while a feedback hypothesis is confirmed amid GDP and EC in the case of LMI and UMI African nations.

(ii) Concerning OP-EC nexus, a consensual liaison is observed in LC African economies though one-way affiliation runs from OP to EC in both LMI and UMI African countries.

(iii) For LI and LMI African nations, a bilateral connectedness is flanked by OP and GDP whereas on the side of UMI African states, a single-directional causation extends from OP to GDP.

(iv) URB and GDP also are characterized by a two-sided relationship in both LI and LMI countries in Africa whilst UMI African nations are defined with one-sided connection running from URB to GDP.

Generally based on the findings discovered from the study, some policy recommendations are briefly drawn as follows;

[3] Details of the D-H Granger causality test results for all country groups employed in the study are available upon request.

(i) Regardless of the stage of development in terms of income levels, direct measures to ensure energy use may be detrimental to the growth of African economy. Therefore, potential risks to energy conservation should not be overlooked when formulating energy conservation policies.

(ii) It has been virtually evidenced that; it is difficult to eliminate the detrimental effect of oil price on energy use as well as economic growth in African economy. Thus, instead of eliminating the harmful effect of oil price, plans should rather be implemented to increase production, thereby significantly improving energy efficiency.

(iii) Urbanization and economic growth are key factors affecting energy use and should be considered in the energy policy formulating process.

(iv) Urbanization together with population growth can be assessed as exogenous factors largely determined by energy use and economic growth. Therefore, decision makers of urbanization and population growth should not erroneously assess whether these two variables are the result of economic growth and energy use. Instead our results show that urbanization and population growth can also promote economic growth and energy use.

Given potential heterogeneity between country groups, the empirical findings together with the policy recommendations are robust to possible transitional dependences and are still valid.

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