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The Relationship between GDP and Biomass Energy Per Capita in Sub-Saharan Africa

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ABSTRACT

The relationship between traditional biomass energy consumption and economic growth is examined in 15 Sub-Saharan Africa countries based on available World Bank data for the period of 1990-2019, in terms of biomass energy per capita and real GDP per capita. Three sets of countries, showing different relations of GDP and biomass are discussed. On one hand, the largest set of countries shows increasing GDP and increasing biomass use per capita. On the other hand, the next largest set of countries shows increasing GDP and decreasing biomass use per capita. There is also a small set of countries with decreasing GDP, with examples of both increasing and decreasing biomass use per capita. For most of these countries we find a positive relationship between biomass energy consumption and GDP, per person. The results indicate that biomass energy use does not necessarily fall with increasing GDP, and also that several countries have introduced successful measures to reduce biomass use.

Keywords: Biomass Energy, Economic Growth, Correlation, Unit Root Test, FMOLS, Co-integration

JEL Classifications: A12, B40, CO1, C10, C22, C23, Q13, Q40, Q47

1. INTRODUCTION

During last decade, the African continent has experienced rapid growth, with an average of 5% yearly increase in GDP overall. Even so, several international crises have affected this growth and a great number of Sub-Saharan African (SSA) countries have persistent poverty and have had slow economic growth for a long time period. The energy sector has recognized importance in economic growth and development both for developed and under developing countries. Energy use in Africa is still low compared to the rest of the world. Additionally, this region with more than 950 million people is the most electricity-poor region in the world, more than 600 million households have no access to electricity, and other millions are connected to an unreliable grid that prohibits them to meet their daily energy service needs. Biomass energy is the primary energy source used by 2.7 billion people and contributes14% of the world's primary energy. It is used in most developing countries particularly in Sub-Saharan African countries and even many Asian countries as the basic energy requirement for poverty reduction (Kouton, 2021).

fIn SSA, around 81% of the population depends on biomass energy for household cooking and economic activities. The dependence on biomass energy consumption across African regions varies between 51% and 57%. Even though the International Energy Agency (IEA) assumes reduction in total energy percentage rate of biomass by 2035, is expected that biomass will still continue to be a significant portion of the energy consumption of African countries (Bildirici and Özaksoy 2016). Supporters of the contribution of biomass energy advocate that better utilisation of this type of energy source would facilitate balance between demand and supply of energy, and increase capabilities to meet energy future demand Elfaki et al. (2018); Dritsaki and Dritsaki (2014); Rault et al. (2014); Kouakou (2011); Bildirici and Özaksoy (2016). Using data from 15 SSA countries, the objective of this paper is to analyse the relationship between biomass energy consumption and economic growth. This is achieved by using Fully Modified Least Squares regression analysis over the 1990-2019 period and then implementing the panel-data approach of Rault et al. (2014).

2. LITERATURE REVIEW

The economic literature has demonstrated that energy consumption contributes to capital and labour productivity, promotes export potential of countries Ucan et al. (2014), creates employment, decreases poverty and improves socio-economic development as well as economic growth. The link between energy consumption and GDP per capita has been analysed by many researchers in different times of the century and report the mixed results have been reported (Pempetzoglou, 2014; Dogan and Walker, 2014; Ackah and Asomani 2015; Kahsai et al., 2012; Fatai, 2014; Aklin et al., 2017; Osigwe and Arawomo, 2015; Mehrara and Rafiei, 2014; Costantini and Martini 2010; Costantini 2009; Saidi and Hammami, 2014; Marinaş et al., 2018; Alege et al., 2016; Alege et al., 2018; Alege et al., 2016; El Hedi and Henni 2014; Fatai, 2014; Richardson, 2010; Amiri and Zibaei, 2012; Elfaki et al., 2018 and Ali et al., 2015).

Biomass energy and economic growth in particular has been analysed by many researchers including Bildirici and Özaksoy (2016); Odhiambo (2009); Maji et al. (2019) as well as Mehrara and Rafiei (2014), who addressed the causal relationships between biomass energy consumption and real GDP by applying the Toda-Yamamoto causality test. The study by Payne about the relationship between biomass energy and real GDP using multivariate analysis during 1949-2007, showed that there is unidirectional causality running from biomass energy to the real GDP. In the same line (Bildirici, 2013) investigated the nexus link between GDP and biomass energy for developed and developing countries (Bolivia, Argentina, Chile, Brazil, Jamaica, Guatemala and Colombia) based on the Augmented Dickey Fully method. The outcome revealed a unidirectional causality run from GDP growth to biomass energy. From 1980 to 2009, the study done by Bildirici using the ARDL method towards the relationship between biomass energy and real GDP on short run and long run showed a unidirectional causality between biomass energy and real GDP. Bildirici and Özaksoy (2016) investigated the processes between economic growth and biomass energy consumption. The results showed a bidirectional causality determined by strong run between parameters. The analysis by (Bildirici and Özaksoy, 2016b) from 1980 for biomass energy and economic growth by applying ARDL and panel co-integration method showed a causal relationship between variables. This was found in some transition countries like Hungry, Croatia, Slovakia and Slovenia and growth hypothesis for the countries such as Romania and Bulgaria. Bildirici and Ozaksoy also were motivated to investigate the link between biomass energy and oil price in USA for the period between 1973 and 2012. The results showed a unidirectional causality between oil price and biomass energy consumption. Bildirici and Ersin (2015b) investigated the relationship between biomass energy and economic growth as well as oil consumption. The results revealed that biomass energy is affected by oil price and economic growth. (Bildirici and Ersin 2015a) Bildirici and Özaksoy (2016a) in a panel analysis of 51 SSA countries during the period for 1980-2009 indicated that biomass energy consumption, population and openness contribute to economic growth. Fatai (2014) has carried out a study for 21 African countries over the years 1970-2006 by using panel co-integration techniques and report2 a bi-directional causality between biomass and economic growth.

3. METHODOLOGY

The relationship between GDP per capita and biomass energy consumption over the period 1990-2019 is investigated. We carry out a country-by-country correlation analysis using Fully Modified Least Squares regression to identify the long-run relationship between biomass and GDP on a per capita basis. In contrast to previous studies, this approach allows for comparison between countries and provides a basis for understanding the interrelations of biomass energy consumption, national economic growth, and policy in diverse sub-Saharan nations. Additionally, in contrast to previous studies, we take into consideration the potential for structural breaks; we employ the unit root and cointegration tests allowing for structural breaks to assess the stability between energy consumption and GDP for 15 African Sub-Saharan Countries.

Before exploring cointegration procedures, it is imperative to establish the order of integration of biomass and GDP variables, by carrying out the unit root test. The process for the unit root test in time series models has gained a good deal of interest in statistics theory. The application of Fuller (1984) and Dickey, Bellas well as Miller (1986) is used in much of the literature. The hypothesis of unit root has important implication in economics because it is always a theoretical implication in economics. The use of unit root test hypothesis facilitates to investigate the no stationarity faced the most macroeconomics data in nature. Specifically, it helps to detect if the trend is stochastic due to the presence of a unit root, or deterministic, as a result of polynomial trends.

Furthermore, when we want to forecast in time series analysis, it is good to make a model for forecasting purposes. Then we require a stationary time series. To test stationarity, referred to in autoregressive modelling, we use the Phillips-Perron and Augmented Dickey-Fuller (ADF) tests.

The ADF test is a statistical significance test which means the test will give results in both null hypothesis tests and alternative hypotheses. Since the null hypothesis assumes the presence of a unit root, the P-value obtained by the test should generally be less than the significance level of 0.05 to reject the null hypothesis. As a result, we will have a probability calculated and probability value from which we will need to make inferences about the time series, whether it is stationary or not.

Consider the following equation for the unit root test

$$y_t = X_t + P_t + \varepsilon_t \quad \text{(Equation 1)}$$

Where, X_t is the deterministic component of the equation.
P_t is the stochastic component of the equation.
ε_t is the stationary error process required to satisfy the properties of zero mean and constant variance.

Then the unit root test is to determine whether the P_t contains a unit root or not. To do this the Dickey-Fuller test uses a simple autoregressive mode (AR) in time series formula.

Let a simple AR model represented as follow, then a time series y_t is generated as

$$y_t = \delta y_{t-1} + \varepsilon_t \text{ (t=1, 2….)} \quad \text{(Equation 2)}$$

y_t is parameter or variable of interest at the time period t, δ_t is a coefficient that explains the unit root while μ_t is a noise or error term

If $\delta = 1$, the unit root is occurring in a time series, and the time series is non-stationary.

$\delta = 1$ by setting at $t = 0$ and y_0 may be random variable, including constant and the distribution fixed and independent for the sample size T.

By using regression model, Equation 2 is developed as follows:

$$\Delta y_t = (\rho - 1) y_{t-1} + \varepsilon_t = \delta y_{t-1} + \varepsilon_t \quad \text{(Equation 3)}$$

Δ is a difference operator while $\delta = \rho$-1. When $\rho = 1$, it means that we get the differencing as the error term. When the coefficient has values smaller than one or larger than one, we can observe the changes according to the past observation.

The Equation 2 tests for a unit root while $y_t = \beta_0 + \delta y_{t-1} + \varepsilon_t$ (Equation 4) tests for a unit root with constant. Finally, the equation to test for a unit root with the constant and deterministic trends with time become

$$y_t = \beta_0 + \beta_{1t} + \delta y_{t-1} + \varepsilon_t \quad \text{(Equation 5)}$$

Given the fact that the sample countries share somes characteristics of being underdeveloped and situated in the sub Saharan region, we are interested also to analyse a panel unit root test

The ADF and Phillips-Perron test are used to test the relationship between parameters.

The Equation 2 is transformed as

$$\gamma_{it} = \delta_1 \gamma_{it-1} + H'_{it}\gamma + \mu_{it} \quad i=1 \ldots N;\ t=1.T \quad \text{(Equation 6)}$$

where H_{it} is the deterministic component and μ_{it} is a stationary process. $\delta_1 \gamma_{it-1}$ is considered as a constant term. The ADF and Phillips-Perron test assumes that residuals are independently and identically distributed in variable series with variance σ^2 and mean zero and $\delta_i = \delta$ for all values of i. The null hypothesis is constructed as H_0: $\delta = 1$ which means that the two variable series have a unit root while the alternative hypothesis H_1: $\delta < 1$ means that two series are stationary.

To allow heterogeneity in the intercept terms, ADF and Phillips-Perron allows for heterogeneity and slope terms for the cross-section units. The ADF and Perron unit root test can be specified as:

$$\gamma_{it} = \delta_1 \gamma_{it-1} + \sum_{i=1}^{n} \delta_i \Delta\gamma_{it-1} + H'_{it}\gamma + \varepsilon_{it}, \quad \text{(Equation 7)}$$

and this equation is reduced as follows:

$$Y_t = \alpha + \delta Y_{t-1} + \varepsilon_t \quad \text{(Equation 8)}$$

Here Y_t is the time series, t is the time index, α and δ are coefficients and ε_t is the error term.

With a constant term and trend, the equation is

$$\Delta Y_t = \alpha + \beta_t + \delta Y_{t-1} + \varepsilon_t \quad \text{(Equation 9)}$$

Finally, the fact that the unit root test of Im, Pesaran and Shin (2003, hereinafter IPS) test is based on averaging individual Augmented Dickey-Fuller (ADF) statistics and is less restrictive; more powerful compared to the tests don't permit for heterogeneity in the autoregressive coefficient developed by Levin et al. (2002) and Jorg Breitung (1997) and Jörg Breitung and Pesaran (2008), it is necessary to use it in order to make comparison with others mentioned above and to control some external factors due to violent exogenous shocks in panel countries data.

The IPS panel unit root test is developed and the Equation 9 becomes:

$$\Delta y_{it} = \alpha_i + \beta_i y_{i,t-1} + p\sum_{i=1}^{p} \delta \Delta y_{it-1} + \varepsilon_{i,t} \quad i = 1, 2, \ldots N;\ t = 1, 2, \ldots, T \quad \text{(Equation 10)}$$

Where y_{it} stands for each variable under consideration in our model, i

α_i is the individual fixed effect and β is selected to make the residuals uncorrelated over time.

Considering that IPS statistics is based on an average of individual Augmented Dickey-Fuller (ADF) statistics, a *t-statistic* for country i based on the country-specific ADF regression is expressed as follows:

$$\bar{t} = \frac{1}{N}\sum_{i=1}^{N} t_{iT}, \quad \text{(Equation 11)}$$

where t_{iT} is the ADF t-statistic for country i

3.1. Co-integration Analysis - Johansen Test

$$Y_t = \beta + \Psi Y_{t-1} + \varepsilon_t \quad \text{(Equation 12)}$$

The approach of Johansen is based on the maximum likelihood estimation of the matrix (Ψ - I) under the assumption of normal distributed error variables. From this, the hypothesis is H_0: r = 0, H_1: r = 1, H_2: r = M-1 are tested using likelihood ratio (LR) tests.

The co-integration model used is based on SVAR model

$$\beta_0 Y_t = \beta + \sum_{i=1}^{k} \beta Y_{it-1} + \varepsilon_t \quad \text{(Equation 13)}$$

$$Y_t = \beta_0 + \beta_{1t} + \sum_{i=1}^{k} \varphi_i Y_{t-1} + \beta' x_t + \sum_{i=0}^{q-1} \beta^{*'} \Delta x_{t-i} + \varepsilon_t \quad \text{(Equation 14)}$$

$$\Delta x_t = P_1 \Delta x_{t-1} + P_{2t} \Delta x_{t-2} + \ldots + P_S \Delta x_{t-s} + \varepsilon_t \quad \text{(Equation 15)}$$

X_t represents K-dimensional I (1) variables which are not co-integrated; the P_i are coefficients for the matrix autoregressive process and ε_t represents the error term. When the study reveals a co integration in maximum eigen values it is necessary to check the stability of co-integration in the long run. The results of the test based on the Hansen Parameter Instability for co integration will reject the null hypothesis at a 1% level of significance indicating that the variables have a long run relationship. After achieving stability between parameters, the further step is to examine the order of integration of the variables, which leads us to examine long-run co-integration by applying Johansen panel co-integration.

3.2. The Fully Modified Ordinary Least Squares (F.M.O.L.S.) Estimator

The use of an OLS model estimator sometimes suffers from a second order asymptotic bias arising from endogeneity and serial correlation and among variables under investigation. Furthermore, this implies that the OLS t-ratio is not asymptotically standard normal, and useless for inference. To solve this issue requires use of an estimator which is consistent, normally distributed and asymptotically unbiased even in the presence of endogenous regressors. The best tools are estimators based on panel versions of the dynamic OLS (DOLS) and fully modified ordinary least squares (FMOLS) procedures. Using econometric analysis, a linear generalised model is applied to develop a FMOLS model.

$$Y_{it} = \beta_0 + \beta_1 X_1 + \varepsilon_{it} \quad \text{(Equation 16)}$$

where Y_{it} is GDP per capita of country *i* in year *t*, GDP is gross domestic product in 2017 constant international dollars using purchasing power parity rates, and X_1 is biomass energy per capita (kg of oil equivalent).

Let the Equation 1 be transformed as follows: $y_{it} = \beta_i + \beta_i X_{it} + \mu_{it}$.

Then the equation is co-integrated with the slope $\beta_{1'*}$,

Let $\varepsilon_{it} = \hat{\mu}_{it}, \Delta X_{it}$ be stationary vector including the estimated residuals and differences. Also, let this equation integrated in the following limit:

$$\Omega_{it} = \lim_{T\to\infty} E\left[T^{-1}\left(\sum_{t=1}^{T} \varepsilon_{iT}\right)\left(\sum_{t=1}^{T} \varepsilon_{iT}\right)'\right] \quad \text{(Equation 17)}$$

F.M.O.L.S. estimators are given as:

$$\varphi = N^{-1} \sum_{i=1}^{N} \left(\sum_{i=1}^{T} (x_{it} - \bar{y}_i)^2\right)^{-1} x \left(\sum_{i=1}^{T} (x_{it} - \bar{x}_i)^2 s^*_{it} - T\lambda_i\right) \quad \text{(Equation 18)}$$

Where $y_{it}^* = (s_{it} - \bar{s}_{it}) - \frac{\hat{\Omega}_{21t}}{\hat{\Omega}_{22t}} \Delta x_{it^*}$ (Equation 19)

$$\hat{\lambda}_t = \hat{\Psi}_{21} + \hat{\Omega}_{21t} - \frac{\hat{\Omega}_{21t}}{\Omega_{22t}} (\hat{\Psi}_{22t} + \hat{\Omega}_{22t}) \quad \text{(Equation 20)}$$

The between-dimension estimator is $\varphi_{GFM} = N^{-1} \sum_{i=1}^{N} \varphi_{kM,t}, where \varphi_{k,M,t}$ is the F.M.O.L.S estimator.

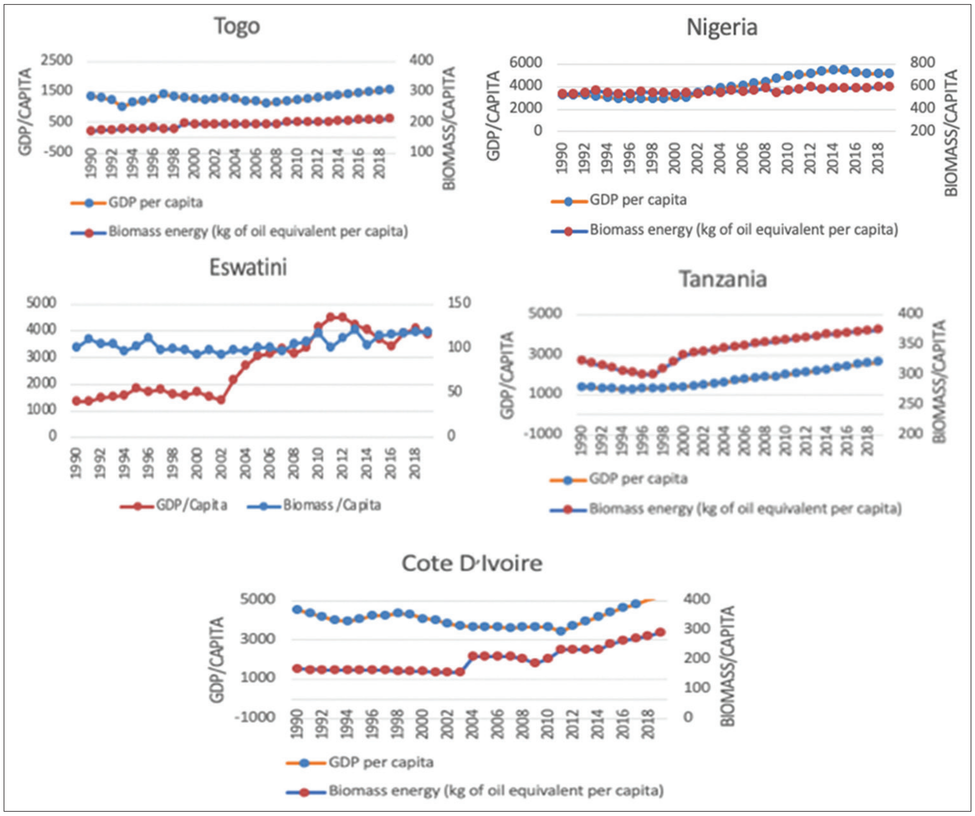
3.3. Variables and Dataset Exploratory Test

Data on biomass energy consumption and economic growth are analyses for 15 SSA countries: Ghana, Angola, Kenya, Zimbabwe, Cameroun, Tanzania, Namibia, Togo, Eswatini, Botswana, Mozambique, Nigeria, Ivory Coast, Senegal and Ethiopia. Annual data from 1990 to 2019 on these 15 countries were collected from the World Bank Data Bank (World Bank, 2020) and are provided in the Supplementary Material. The econometric data includes biomass renewable energy consumption and waste in thousands of tons of oil equivalent, gross domestic product (GDP) in billions of constant 2017 USD, biomass energy in billions of constant 2015 USD, GDP per capita, total energy use in millions (GJ). Total energy consumption was selected to represent all variables of energy source. The energy data are originally compiled by the International Energy Agency (IEA). IEA data for economies that are not members of the Organisation for Economic Co-operation and Development (OECD) are based on national energy data adjusted to conform to annual questionnaires completed by OECD member governments. The biomass energy use, in this study it comprises Combustible renewable and waste comprise solid biomass, liquid biomass, biogas, industrial waste, and municipal waste, measured as a percentage of total energy use. It measured as the percentage of total energy consumption. The conventional unit of biomass energy use by household is measured in Giga Joule and was expressed in relation to GDP per kilogram of oil equivalent per capita. GDP per unit of energy use is the PPP GDP per kilogram of oil equivalent of energy use. PPP GDP is gross domestic product converted to current international dollars using purchasing power parity rates based on the 2017 ICP round.

As illustrated in Figures 1-3, the data are shown here in three country groupings: (1) those for which both GDP and biomass use per capita has been increasing, (2) those for which GDP per capita has been increasing and biomass per capita has been decreasing, and (3) those for which GDP has been decreasing. In general, the three categories present different outcomes of the sample countries. Both GDP and biomass per capita increasing: Tanzania, Togo, Eswatini, Nigeria and Cote d'Ivoire.

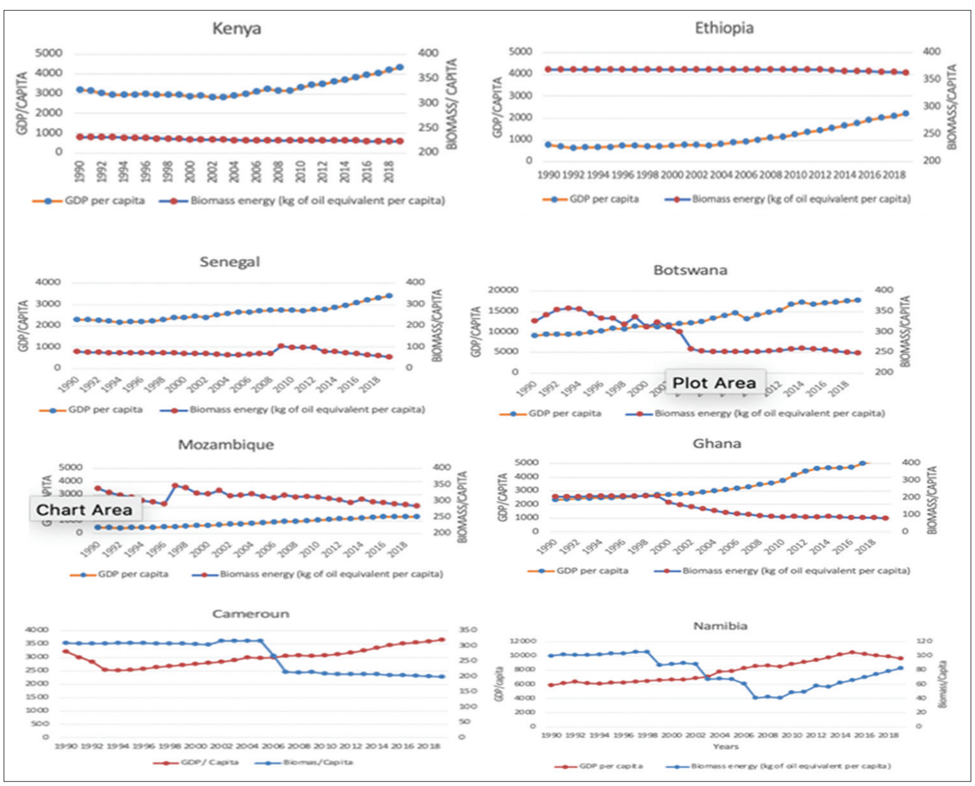
Group 1 shows data for the countries in which both GDP and biomass per capita has been increasing. In addition, we tested for normality to ensure the data are appropriate for the statistical

Figure 1: Countries in which both GDP and biomass per capita has been increasing during last three decades.



Source: Researchers' computation from EViews 12

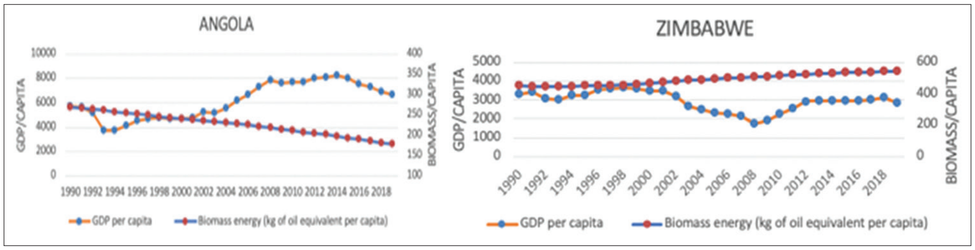
Figure 2: Countries in which GDP has been increasing with a decreasing biomass per capita during last three decades



Source: Researchers' computation from EViews 12

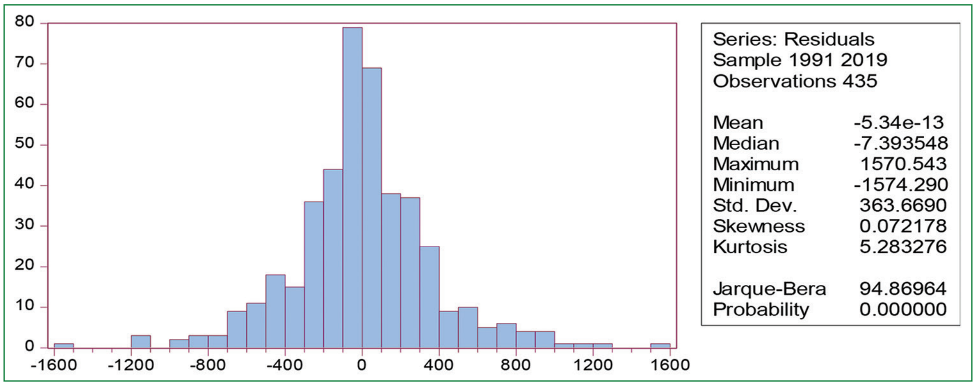
analysis, using the test of Jarque and Bera (1980, 1987) based on the skewness and kurtosis k computed from the sample, which has gained great acceptance among econometricians. According to Figure 4 table, the data are well distributed. As data for this study may not be error-free, we highlight this test result as a foundation of the analysis that follows.

Figure 3: Countries in which both GDP and biomass per capita do not show a steady trend during last three decades.



Source: Researchers' computation from EViews 12

Figure 4: Histogram of used data distribution.



Source: Researchers' computation from EViews 12

3.4. Data Analysis

The full analysis of relationship between GDP and biomass energy per capita in Sub-Saharan Africa was achieved by applying successively three econometric analyses, namely unit root test, co-integration estimation and full modified model after running dynamic ordinary Least Squares regression (Appendix 1).

The first analysis was Unit root test. The unit root tests are used to determine if the variables are stationary or integrated in levels: I (0) and/or I (1), because time series data may face an issue of multi collinearity problem. By using the maximum lag of 6, the results of the A.D.F. (Augmented Dickey-Fuller) and ADF - Fisher Chi-square, ADF - Choi Z-stat unit root (references) tests are given in Appendix 2 and 3.

The second analysis was the Johansen co-integration test. The Johansen co-integration test is used to allow variables in the system to have an equal order of integration. Country by Country Correlation and Dynamic Ordinary Least Squares (DOLS) regression was needed to evaluate if variables have a significance relationship as well as heterogeneous variance structures between variables. Lastly, we implemented the Dynamic Ordinary Least Squares (DOLS) regression and the Fully Modified Ordinary Least Squares (FMOLS) estimates first proposed by Pedroni and suggested by Phillips and Perron (1988); to solve the problems of asymptotic bias and nuisance parameter dependency associated with cointegrating vector estimates occurred in heterogeneous panel. The results produced by this estimator manifests consistent standard errors and *t*-statistics in the presence of endogenous regressors. The Full presentation of the model is provided as mathematical appendix.

4. ECONOMETRIC RESULTS AND DISCUSSION

4.1. Unit Root Test Results

The results about unit roots test (Appendix 2) show that biomass energy consumption and economic growth contain unit root problem in levels series with none and intercept as well as trend since the P-values for sample country by country are less than $\alpha = 0.05$. After 1st, second up to fourth differencing for ADF and Phillips-Perron, the variables are found to be stationary. This indicates that biomass energy consumption and economic growth have a unique order of integration. We conclude that results are robust and consistent. This result is similar to the findings of the Ozturk et al. (2010) and Ozturk et al. (2015) about Economic Growth and Biomass Consumption Nexus using Dynamic Panel Analysis for Sub-Sahara African Countries. The results of the growth hypothesis are supported and similar to the results obtained for Bulgaria and Romania by Granger Causality method. Additionally, this the study has analysed the IPS and Pesaran unit root tes. The result from this analysis shows that the claim towards the null hypothesis of unit root cannot be rejected for the variables in levels. Then we used the unit root test in the first differences and found that the result about the variables reject the null hypothesis, implying that the levels are nonstationary, and the first differences are stationary. The results about (Levin et al., 2002) Levin, Lin and Chu, IPS, ADF – Fisher Chi-squared and Pesaran tests are presented in Appendix 3.

4.2. Country by Country Correlation and Dynamic Ordinary Least Squares (DOLS) Regression Analysis

To begin the analysis, we use a dynamic least square regression (DOLS) to consider the correlation of biomass and GDP per capita relationship, as show in Table 1 Pearson's correlation coefficients

Table 1: Correlation and regression analysis of sample countries between GDP per capita and biomass energy by using of the Dynamic Ordinary Least Squares (DOLS) regression

Dependent variable: GDP per capita					
S. No.	COUNTRIES	Corr.Coeff	Dynamic Ordinary Least Squares (DOLS)		
			Variable	Contribution value Of biomass to GDP	R. square
1.	Tanzania	0.934	BIOM.ENERGY	18.24614 (8.948111***)	0.866
			GDP constant	−4465.4	
2.	Togo	0.519	BIOM.ENERGY	0.447712 (0.045974)	0.362
			GDP constant	1072.51	
3.	Eswatini	0.529	BIOM.ENERGY	−34.9943 (−0.72729)	0.95
			GDP constant	55338.17	
4.	Nigeria	0.86	BIOM.ENERGY	−17.4002 (−3.19994***)	0.223
			GDP constant	6266.13	
5.	Cote D'Ivoire	0.389	BIOM.ENERGY	5.48969 (1.760005*)	0.159
			GDP constant	3019.191	
6.	Senegal	−0.151	BIOM.ENERGY	−3.71064 (-0.36845)	0.019
			GDP constant	2873.473	
7.	Ethiopia	−0.948	BIOM.ENERGY	−236.165 (−8.26296***)	0.898
			GDP constant	88186.65	
8.	Kenya	−0.642	BIOM.ENERGY	284.1541 (6.986456***)	0.927
			GDP constant	−63187.7	
9.	Ghana	−0.855	BIOM.ENERGY	−4.92036 (−2.2693**)	0.937
			GDP constant	2383.709	
10.	Mozambique	−0.598	BIOM.ENERGY	−0.19309 (−0.22267)	0.985
			GDP constant	391.4453	
11.	Botswana	−0.857	BIOM.ENERGY	10.60083 (1.798845*)	0.969
			GDP constant	4423.577	
12.	Cameroun	−0.8	BIOM.ENERGY	−5.95046−5.21089***	0.693
			GDP constant	4573.762	
13.	Namibia	−0.724	BIOM.ENERGY	−11.0015 (−1.72388*)	0.929
			GDP constant	6587.404	
14.	Zimbabwe	−0.504	BIOM.ENERGY	−57.436 (−2.03896**)	0.423
			GDP constant	28106.43	
15.	Angola	−0.807	BIOM.ENERGY	−41.1356 (−4.20953***)	0.651
			GDP constant	15400.58	

Source: Researchers' computation from EViews 12. ***, ** and * indicate the statistical significance of the estimated parameters at 1%, 5% and 10% respectively. The number in brackets are the t-statistics

show a positive correlation data for the group 1 countries in which both GDP and biomass per capita has been increasing. These countries are Tanzania, Togo, Eswatini, Nigeria and Cote D'Ivoire. In this group, Tanzania has a high correlation of 0.934 while Cote D'Ivoire has a small correlation of 0.389. Group two represents the data for the countries in which GDP per capita has been increasing, but biomass per capita has been decreasing. The countries are Senegal, Ethiopia; Kenya; Ghana; Mozambique; Botswana; Angola, Namibia, and Cameroun. The relationship between two variables in these countries is negative and high for Ethiopia, Ghana; Botswana and Cameroun while the remaining have a moderate and lower correlation. And for Zimbabwe, which has had decreasing GDP over the time period, there is a moderate negative correlation. On the other hand, DOLS analyses is conducted to allow heterogeneous variance structures between variables. The outcome from this estimator with one lead and two lags square yield the highest value R^2 and are statistically significance. This demonstrates that in panel data of 15 Saharan African countries, GDP data are affected by African data of biomass consumption.

4.3. Johansen Co-integration Test

Table Appendix 4 exhibits the Johansen test results. The Johansen co-integration test results with trace statistics and maximum eigen values support the co-integration relationships of economic growth and biomass consumption found in the Johansen test after first difference. This means that in two cross-sections (biomass and GDP), there is a long-run equilibrium relationship between biomass energy consumption and economic growth.

The analysis made on co-integration used Johansen panel co-integration has demonstrates that there is co-integration between levels and the trace and maximum-eigen value test shows the presence of two co-integrating vectors in the estimated model led us to conclude that there is a co-integration relationship between biomass energy consumption and GDP per capita for the countries under the period of 1990-2019. After getting co-integration in maximum Eigen values, the study has demonstrated that there is a stability of parameters in the long run co-integration at a 1% based

Table 2: Fully Modified Least Squares (FMOLS) for each country

Dependent variable: GDP per capita				
Countries	**Variable**	**Contribution value of biomass to GDP**	**R. square**	**Decision**
Tanzania	Biomass energy	18.26076 (9.016297***)	0.866505	Long run+
	GDP constant	−4455.88***		
Togo	Biomass energy	7.449655 (2.551075**)	0.32974	Long run+
	GDP constant	−148.289		
Eswatini	Biomass energy	99.81509 (3.053868***)	0.332061	Long run+
	GDP constant	−7795.19**		
Nigeria	Biomass energy	44.76182 (8.079248***)	0.712724	Long run+
	GDP constant	−21136.8***		
Cote D'Ivoire	Biomass energy	5.616237 (1.787382*)	0.169147	Long run+
	GDP constant	2944.368		
Kenya	Biomass energy	297.8737 (7.75463***)	0.923385	Long run+
	GDP constant	−66333.2***		
	Trend value in long term	134.583***		
Botswana	Biomass energy	10.60083 (1.798845*)	0.968627	Long run+
	GDP constant	4423.577**		
	Trend value in long term	375.9809***		
Ghana	Biomass energy	7.166415 (2.174166***)	0.936881	Long run+
	GDP constant	170.5307		
	Trend value in long term	150.8767***		
Senegal	Biomass energy	−4.92036 (−2.26929**)	0.937403	Long run−
	GDP constant	2383.709***		
	Trend value in long term	39.37992***		
Ethiopia	Biomass energy	−162.583 (−6.32508***)	0.965435	Long run−
	GDP constant	60681.48***		
	Trend value in long term	25.33186***		
Cameroun	Biomass energy	−1.68704 (−1.01639)	0.804447	Not significant
	GDP constant	3072.676***		
	Trend value in long term	24.60692**	0.82422	
Mozambique	Biomass energy	−4.31638−0.5782***		Not significant
	GDP constant	5766.688	0.485474	
	Trend value in long term	170.1434		
Namibia	Biomass energy	−11.0015 (−1.72387*)	0.928841	Long run−
	GDP constant	6587.403***		
	Trend value in long term	146.4348***		
Zimbabwe	Biomass energy	−13.9295*** (−6.66022***)	0.836931	Long run−
	GDP constant	9781.688***		
Angola	Biomass energy	−15.9259*** (−4.44131***)	0.780977	Long run−
	GDP constant	7944.722***		
	Trend value in long term	127.649***		

Source: Researchers' computation from EViews 12. ***, ** and * indicate the statistical significance of the estimated parameters at 1%, 5% and 10% respectively. The number in brackets are the t-statistics on the Hansen Parameter Instability between series. This result has motivated to examine the order of integration and found that they are 3 co-integrations in trace values and 3 in Maximum eigen values. Furthermore, the analysis based on Hansen co integration test shows that the series are cointegrated appendix 5.

4.4. Long-time Dynamic and Consistent Relationship between Biomass Energy and GDP

The Dynamic Ordinary Least Squares (DOLS) regression and the Fully Modified Ordinary Least Squares (FMOLS) estimates summarized in Table 1, shows the long run correlation between the variables, and the results of the Dynamic Ordinary Least Squares (DOLS) regression. Now we use the Fully Modified Ordinary Least Squares (FMOLS) regression to further investigate the nature of this long run relationship. By using FMOLS, the results show that eight countries such as Tanzania, Togo, Eswatini, Nigeria, Cote D, Ivoire; Kenya, Ghana and Botswana have demonstrated a positive relationship between GDP and economic growth while five countries including Senegal, Ethiopia, Namibia, Zimbabwe and Angola demonstrate a negative long run relationship between parameters. The remaining countries such as Cameroun and Mozambique reveal insignificant relationship. Ouedraogo (2017) argues that the FMOLS produces more robust results and requires fewer assumptions compared to the DOLS, and therefore forms the focus of our discussion. The long run variable estimates are provided in the Supporting Information. The result of regression FMOLS presented in the Table 2 shows that the coefficient of biomass energy is positive for a great number of countries and negative in a few countries. The FMOLS estimation uses the heterogenous estimation of DOLS with one lag and two lags the regressor (energy) is found statistically significant at the 1% 5% and 10% confidence levels. The estimations from heterogeneous variance structure indicates that an increase in biomass energy consumption when other things equal, is associated with an increase in GDP per capita for Tanzania, Togo, Eswatini, Nigeria, Cote d, Ivoire Kenyan Ghana and Botswana respectively. Thus, wood biomass energy consumption can be interpreted as "normal good" for these countries. However, an increase in biomass energy per person when other things equal, is associated with a GDP decrease per capita in Senegal, Ethiopia, Namibia, Zimbabwe and Angola. Thus, wood energy consumption can be interpreted as "inferior good" for these countries.

The positive trend and constant coefficient with their negative signs are statistically significant and expounds how quickly variables converge to equilibrium. Estimation methodology mainly consider homogenous DOLS estimation since it yields the highest R-square and adjusted R-square. Estimations of OLS and DOLS show that GDP and biomass have a long run relationship. The study shows that an adjustment term which captures the potential contribution of heterogeneity from the dynamics of the panel works to produce minimal size distortions in these panel FMOLS statistics. The results for whole sample countries based on co-integration equation deterministic and trend in variables (Panel Fully Modified Least Squares (FMOLS) of panel data countries reveals that the Contribution value of biomass to GDP (independent variable) is 4.041862 and the coefficient of determination (R-squared) is 0.987476. This test rejects the null hypothesis at 5% of confidence interval of non-co-integration in long run period for all sample countries with the P- value of 0.0901. The results indicate the existence of a positive relationship between biomass energy consumption and GDP per capita for sample panel countries. An increase in biomass energy consumption of 1 koe per capita is related to increase economic growth of 4 US dollar per capita for the sample sub-Saharan countries in general, other factors influencing economic growth held constant. This results is similar to the findings of Ouedraogo (2017) and Ozturk and Bilgili 2015) for non-biomass energy, for which there has generally been found a positive relationship between energy and GDP. Investigated the causality relationship between biomass energy consumption and the co-integration by using economic growth in the transition countries during a period from 1990 to 2011. Fully modified ordinary least square output demonstrates that o biomass energy consumption has a significant positive effect on the GDP.

In sum, the evidence suggests that, in both panel datasets and in individual cross-sections, there is a long-run equilibrium relationship between biomass energy consumption and economic growth.

5. CONCLUSIONS AND POLICY IMPLICATIONS

This study examines the relationship between biomass energy consumption and economic growth. Most of the countries considered show upward trend in both GDP per capita and biomass energy use per capita. This was observed in Tanzania, Togo, Eswatini, Nigeria, Cote d'Ivoire, Kenya, Botswana and Ghana. These results support the idea that woody biomass energy consumption has a positive long run relationship with GDP and can be accepted as "normal good" However, some countries have upward trended of GDP per capita and downward trending of biomass energy per capita. These countries are Senegal, Namibia, Zimbabwe, Ethiopia and Angola. There are also two countries for which GDP per capita has fallen and the relationship between variables is not statistically significant: Cameroun and Mozambique. The categories mentioned above show some African countries have reduced the use of biomass energy considerably while others have continued to use the biomass energy. In two last categories, biomass energy consumption is behaving as a "normal good." Future research can evaluate the causal relationship between biomass energy consumption and economic growth using time series data with fixed and random effect models.

The results about unit roots test (Appendix 2 and 3) show that biomass energy consumption and economic growth contain unit root problem in levels series with none and intercept as well as trend. After 1st, second up to fourth differencing for ADF and Phillips-Perron, the variables are found to be stationary. This demonstrates that Sub Sahara African countries are, cross sectionally correlated, which revealed the presence of similar regulations in different domains such as economy, energy and others. Additionally, the study has analysed the panel data based on the IPS and Pesaran unit root test with without trend effect as well as intercept and trends in variables. The results are both presented in Appendix 3. The two variables demonstrate that the results reject the null hypothesis in level of being non-stationary and stationary in first-differences (at the 1% significance level).

This indicates that biomass energy consumption, economic growth has unique order of integration. We conclude that results are robust and consistent. The analysis made on co-integration used Johansen panel co-integration has demonstrates that there is co-integration between levels and the trace and maximum-eigen value test shows the presence of two co-integrating vectors in the estimated model led us to conclude that there is a co-integration relationship between biomass energy consumption and GDP per capita for the countries under the period of 1990-2019. After getting co-integration in maximum Eigen values, the study has demonstrated that there is a stability of parameters in the long run co-integration at a 1% based on the Hansen Parameter Instability between series. This result has motivated to examine the order of integration and found that they are 3 co-integrations in trace values and 3 in Maximum eigen values. Based on different test conducted within the test, the study found a significance positive influence of biomass energy consumption on economic growth for SSA.

The result of regression FMOLS shows that the coefficient of biomass energy is positive for one group of countries including Ghana, Botswana, Kenya, Cote d' Ivoire, Eswatini, Togo and Tanzania and negative for other group of countries including Namibia, Mozambique, Cameroun, Ethiopia and Senegal in sample covering a period between 1990 and 2019. The results reveal the arguments for valid equilibrium long-run among the variables. The wood fuel consumption affects economic growth negatively, both directly and indirectly. The possible reason of this negativity is that In Sub-Saharan Africa (SSA), people heavily rely on "traditional biomass energy" especially for cooking, lighting and heating considered other regions. The negative sign reveals that there could be a mechanism for the countries with a negative relationship association to correct the disequilibrium biomass energy conception and economic growth.

However, the relationship between GDP and biomass energy consumption is different according to the country characteristics, location, policy used economic development and other factors. Overall, we find (1) the overall statistical analysis based on correlation study confirms that biomass energy consumption is negatively correlated with GDP (2) some countries have had effective policy to reduce biomass energy use; (3) other countries, possibly including some who have had policy to reduce biomass energy use, are still not successful. This demonstrate that wood fuel consumption in some countries is negatively associated with economic growth. In Sub-Saharan Africa (SSA), people heavily rely on traditional biomass energy especially for cooking, lighting and heating considered other regions. These groups show that African countries react in different ways to energy shock so that some countries become net energy exporters while others become net energy importers (energy-dependent) after structural break dates. In sum, the coefficient of biomass energy per capita and GDP is significant and positively related to economic growth within eight countries; five has a negative relationship while two countries are not statistically significant.

Although the International Energy Agency (IEA) has projected a decrease in total energy rate of biomass and wastes by 2035, this type of energy will still have substantial effect on the country's energy consumption (Felix and Gheewala 2011). In Africa, almost 80% of the population utilize traditional biomass energy particularly for cooking. As consequences, the countries that are heavily depend on tradition biomass energy are said to suffer from poverty due to high biomass ratios in total energy, especially for woody biomass. This finding is similar to the study done by Wolde-Rufael (2006) in 17 African countries and reports a bi-direction result, with a relationship running from GDP to electricity consumption for six countries and another running form electricity to the GDP. On the same continent, the work done in East African countries using panel ECM demonstrates that a growth hypothesis runs from GDP to electricity consumption. As for example, for Felix and Gheewala (2011a) and Felix and Gheewala (2011b) reported that with growing urbanizing, charcoal use has increased, driving up consumption of biomass. The result obtained for this group of countries are similar to the study undertaken by M. Bildirici and Ersin (2015b) who addressed the relation between electricity and economic growth as well as M. Bildirici and Ersin (2015b) who analyse the co-integration and causality relationship existent between biomass energy and GDP in the transition countries for the period from 1990 to 2011. Fully modified ordinary least square results of the study show that biomass energy consumption has a positive effect on the economic growth. M. Bildirici and Özaksoy (2016b) examined the relationship between biomass energy consumption and economic growth for the European transition countries for the period between 1980 and 2011; Ozturk and Bilgili (2015) who analysed the long-run dynamics of biomass energy and economic growth by using the dynamic panel for 51 SSA for the 1980-2009 period and others like Shahbaz et al. (2016) for the countries including Brazil, Russia, India, China and South Africa. All econometric results reveal that biomass energy consumption induce economic growth and the feedback hypothesis is supported for the sample countries. Finally, this also reflects the findings obtained in Cameroon, South Africa and Zambia by El Hedi and Henni (2014) as well as to the work of A pergis and Payne (2010) done in USA for the period of 1949-2007. As a policy implication, energy conservation policies based on biomass energy consumption that aim at to increase economic growth should be implemented with care without causing a decline in regional economic growth. Therefore, Sub-Sahara African countries should technologically invest more on renewable energy sources. Policies on usage of biomass energy should aim to reduce environmental degradation; minimize carbon dioxide emissions; promote energy independence to support economic growth.

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APPENDICES

Appendix 1: The unit root test analysis with intercept and trends based on ADF test results

Countries	SERIES	At levels	At first difference	Second difference
	Variables	P-value	P-value	P-value
Tanzania	Biomass energy.	0.0337*	0.1846	0.0047*
	GDP	0.0009*	0.1785	0.0000*
Togo	Biomass energy.	0.1375	0.0001*	0.0002*
	GDP	0.9953	0.0107*	0.0033*
Eswatini	Biomass energy.	0.0687	0.0000*	0.0000*
	GDP	0.4319	0.062	0.0026*
Nigeria	Biomass energy.	0.0129*	0.0000*	0.0004*
	GDP	0.5496	0.3836	0.0003*
Cote D'Ivoire	Biomass energy.	0.6461	0.002*	0.0000*
	GDP	0.9995	0.1217	0.0000*
Senegal	Biomass energy.	0.8065	0.0006*	0.0000*
	GDP	0.9214	0.0092*	0.0000*
Ethiopia	Biomass energy.	0.995	0.2614	0.0002*
	GDP	0.9108	0.0022*	0.0000*
Kenya	Biomass energy.	0.1829	0.5173	0.0072*
	GDP	0.9456	0.0019*	0.0001*
Ghana	Biomass energy.	0.9463	0.0895	0.0000*
	GDP	0.8416	0.0825	0.0004*
Mozambique	Biomass energy.	0.2003	0.0001*	0.0000*
	GDP	0.1328	0.0533	0.0000*
Botswana	Biomass energy.	0.6432	0.0009*	0.0000*
	GDP	0.1698	0.0003*	0.0001*
Cameroun	Biomass energy.	0.268	0.0391*	0.0002*
	GDP	0.0001*	0.1365	0.0008*
Namibia	Biomass energy.	0.5812	0.8376	0.0000*
	GDP	0.2244	0.0908*	0.0000*
Zimbabwe	Biomass energy.	0.2046	0.6962	0.004*
	GDP	0.6346	0.0754	0.0000*
Angola	Biomass energy.	0.9914	0.3346	0.0004*
	GDP	0.3241	0.224	0.0002*

Source: Researchers' computation from EViews 12. Null hypothesis: Series GDP and biomass energy are stationary; Level of significance: *P<0.5; ADF: Augmented Dickey-Fuller.
*Denotes acceptance of the hypothesis of stationarity at the 0.05 level

Appendix 2: Cross-sections unit root test with individual linear trends and automatic selection of maximum lags

Countries	Method	LEVELS		First diff		Second diff	
		Statistic	Prob.**	Statistic	Prob.**	Statistic	Prob.**
Ethiopia	ADF - Fisher Chi-square	0.19698	0.9955	14.8862	0.0049	39.1301	0.0000
	ADF - Choi Z-stat	2.77247	0.9972	−2.46167	0.0069	−5.44391	0.0000
Kenya	ADF - Fisher Chi-square	3.50999	0.4764	13.895	0.0076	28.5819	0.00000
	ADF - Choi Z-stat	0.49443	0.6895	−2.02084	0.0216	−4.38619	0.00000
Angola	ADF - Fisher Chi-square	2.27093	0.6861	5.18214	0.2691	32.5894	0.00000
	ADF - Choi Z-stat	1.36225	0.9134	−0.83869	0.2008	−4.8645	0.00000
Tanzania	ADF - Fisher Chi-square	20.7889	0.0003	6.82579	0.1454	31.4243	0.00000
	ADF - Choi Z-stat	−3.49849	0.0002	−1.28635	0.0992	−4.66282	0.00000
Namibia	ADF - Fisher Chi-square	4.07383	0.3961	5.15342	0.2719	53.1603	0.00000
	ADF - Choi Z-stat	−0.39058	0.3481	−0.24845	0.4019	−6.57025	0.00000
Zimbabwe	ADF - Fisher Chi-square	4.0831	0.3949	5.89482	0.2071	32.8278	0.00000
	ADF - Choi Z-stat	−0.34037	0.3668	−0.65298	0.2569	−4.79079	0.00000
Togo	ADF - Fisher Chi-square	3.97779	0.409	27.5145	0.0000	28.7105	0.00000
	ADF - Choi Z-stat	1.06329	0.8562	−4.25867	0.0000	−4.44752	0.00000
Eswatini	ADF - Fisher Chi-square	7.0364	0.134	30.4827	0.0000	32.5243	0.00000
	ADF - Choi Z-stat	−1.17194	0.1206	−4.24986	0.0000	−4.79535	0.00000
Botswana	ADF - Fisher Chi-square	4.42904	0.351	30.2051	0.0000	108.822	0.00000
	ADF - Choi Z-stat	−0.41583	0.3388	-4.62995	0.0000	−9.1545	0.00000
Mozambique	ADF - Fisher Chi-square	7.25421	0.123	25.2281	0.0000	87.5141	0.00000
	ADF - Choi Z-stat	−1.38167	0.0835	−3.85383	0.0001	−8.44391	0.00000
Nigeria	ADF - Fisher Chi-square	9.89408	0.0423	22.8418	0.0001	31.8396	0.00000
	ADF - Choi Z-stat	−1.48763	0.0684	−3.05494	0.0011	−4.79415	0.00000
Cote d'Ivoire	ADF - Fisher Chi-square	0.87471	0.9282	16.6413	0.0023	43.0111	0.00000
	ADF - Choi Z-stat	2.5886	0.9952	−2.85992	0.0021	−5.78195	0.00000
Senegal	ADF - Fisher Chi-square	0.59365	0.9638	24.1951	0.0001	63.4307	0.00000
	ADF - Choi Z-stat	1.61221	0.9465	−3.95536	0	−7.16139	0.00000
Ghana	ADF - Fisher Chi-square	0.45526	0.9777	9.816	0.0436	41.0165	0.00000
	ADF - Choi Z-stat	1.84622	0.9676	−1.93184	0.0267	−5.56379	0.00000
Cameroun	ADF - Fisher Chi-square	22.2688	0.0002	10.4672	0.0333	31.3782	0.00000
	ADF - Choi Z-stat	−3.1739	0.0008	−2.02069	0.0217	−4.74331	0.00000

Source: Researchers' computation from EViews 12. **Pro Probabilities for Fisher tests are computed using an asymptotic Chi-square distribution. All other tests assume asymptotic normality. The Colum first and second difference are found to be statistically significant. Series GDP and biomass energy are stationary; Level of significance: P<0.5; denotes acceptance of the hypothesis of stationarity

Appendix 3: Panel summary of unit root tests

Individual effects without trend	Levin, Lin and Chu		Im-Pesaran-Shin		ADF - Fisher Chi-square		PP - Fisher Chi-square	
SERIES	Level	First Difference	Level	First Difference	Level	First Difference	Level	First Difference
Biomass	0.86567	−4.87310	2.97172	−7.90313	13.3100	128.806	15.6527	205.58
	(0.8067)	(0.000)	(0.9985)	(0.000)	(0.9963)	(0.000)	(0.9855)	(0.000)
GDP	4.01742	−4.28277	6.26454	−5.17356	6.23029	79.7070	4.19103	112.585
	(1.000)	(0.000)	(1.000)	(0.000)	(1.0000)	(0.000)	(1.0000)	(0.000)
With intercept and trend								
Biomass	0.18979	−4.80738	0.81505	−6.44031	30.4875	102.752	33.6020	687.589
	(0.5753)	(0.000)	(0.7925)	(0.000)	(0.4409)	(0.000)	(0.297)	(0.000)
GDP	−2.23716	−2.75821	−0.21235	−4.04216	41.3625	68.8788	46.0006	121.478
	(0.0126)	(0.0029)	(0.4159)	(0.000)	(0.0811)	(0.0001)	(0.0311)	(0.000)

Source: Researchers' computation from EViews 12. Probabilities for Fisher tests are computed using an asymptotic Chi-square distribution. All other tests assume asymptotic normality. The number in brackets are the probability values

Appendix 4: Johansen Cointegration test (GDP and biomass energy consumption) with Linear deterministic trend: Lags interval (in first differences)

Hypothesized No. of CE (s)		Trace test			Max-Eigen test		
Cross-section		Statistics	Critical value	Probability	Statistics	Critical value	Probability
Tanzania	None*	15.09876	15.49471	0.0573	15.01325	14.26460	0.0380
	Atmost1				0.085502	3.841466	0.7700
Togo	None*	41.73886	15.49471	0.0000	33.47227	14.26460	0.0000
	Atmost1				8.266597	3.841466	0.0040
Eswatini	None*	15.66084	15.49471	0.0472	9.262023	14.26460	0.2650
	Atmost1				6.398818	3.841466	0.0114
Nigeria	None*	28.39645	25.87211	0.0237	16.32729	19.38704	0.1318
	Atmost1				12.06916	12.51798	0.0593
CoteD'Ivoire	None*	28.39645	25.87211	0.0237	16.32729	19.38704	0.1318
	Atmost1				12.06916	12.51798	0.0593
Group 2 shows the data for the countries in which GDP per capita has been increasing, but biomass per capita has been decreasing							
Senegal	None*	25.84147	25.87211	0.0504	23.04624	19.38704	0.0140
	Atmost1				2.795233	12.51798	0.8999
Ethiopia	None*	34.55132	25.87211	0.0032	19.69715	19.38704	0.0451
	Atmost1				14.85417	12.51798	0.0200
Kenya	None*	17.86051	15.49471	0.0216	17.07175	14.26460	0.0175
	Atmost1				0.788767	3.841466	0.3745
Ghana	None*	28.58551	25.87211	0.0224	15.78678	19.38704	0.1546
	Atmost1				12.79872	12.51798	0.0449
Mozambique	None*	22.66097	15.49471	0.0035	13.39040	14.26460	0.0684
	Atmost1				9.270573	3.841466	0.0023
Botswana	None*	24.15686	25.87211	0.0805	20.61000	19.38704	0.0331
	Atmost1				3.546854	12.51798	0.8062
Cameroun	None*	34.29086	25.87211	0.0035	25.48604	19.38704	0.0057
	Atmost1				8.804815	12.51798	0.1927
Namibia	None*	27.07267	25.87211	0.0353	22.21911	19.38704	0.0189
	Atmost1				4.853567	12.51798	0.6175
Group 3 shows the data for the two countries in which GDP has been decreasing							
Zimbabwe	None*	26.21331	15.49471	0.0009	21.40231	14.26460	0.0032
	Atmost1				4.810991	3.841466	0.0283
Angola	None*	17.35037	15.49471	0.0260	15.79764	14.26460	0.0284
	Atmost1				1.552733	3.841466	0.2127

Source: Researchers' computation from EViews 12. *Trace test indicates 1 co-integrating equation (s) at the 0.05 level, *Denotes rejection of the hypothesis at the 0.05 level, Probabilities are computed using asymptotic Chi-square distribution

Appendix 5: Hansen co-integration test

Series: GDP/Capita Energy biomass				
Null hypothesis: Series are cointegrated				
Cointegrating equation deterministic: C @TREND				
Lc statistic	**Stochastic Trends (m)**	**Deterministic Trends (k)**	**Excluded Trends (p2)**	**Prob.***
0.540634	1	1	0	0.0779

*Hansen (1992b) Lc (m2=1, k=1) p- values, where m2=m-p2 is the number of stochastic trends in the asymptotic distribution. Source: Researchers' computation from EViews 12