The Impact of Renewable Energy Consumption and Institution Quality on Economic Growth in Sub-Saharan Africa Countries

Edmond Kamanda[1], Yang Lanpin[1], Brima Sesay[2]
1. School of Economics, Wuhan University of Technology, Wuhan, China
2. Department of Economics and Commerce, Fourah Bay College, University of Sierra Leone
Emails: edmondkamanda@gmail.com, yanglanpin01@163.com, brimasesay30@gmail.com

Abstract
This paper investigates how renewable energy consumption impacts economic growth in Sub-Saharan Africa (SSA). In order to further enrich the debate around renewable energy policy direction and its corresponding effects on growth, we examine the interaction effect of renewable energy consumption and institutions quality on growth. In doing so, panel data set were collected for a sample of 45 SSA countries covering the period 1990-2020. The study employed a dynamic panel estimation technique with a view of evaluating the relative impact of the renewable energy consumption on growth. The results revealed that renewable energy consumption alone has very little impact on growth performance in SSA. However, the simultaneous interaction of renewable energy consumption with institutions quality brings about positive and significant impact on growth. This confirmed that the positive impact of renewable energy consumption on growth is conditional on the quality of institutions, especially as it relates to, government effectiveness, control of corruption, the rule of law and the regulatory quality. For policy, our results imply that governments in SSA should first strengthen their institutions while adopting gradual approach to green energy policies.
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1 Introduction

The uninterrupted energy supply is considered essential for the economic development of both developed and developing countries (Majeed and Luni 2019; Saudi et al., 2019). In the present era, it seems difficult to ensure and sustain the production process and supply of products and services without energy usage (Esen and Bayrak, 2017). The advancement and economic performance of an economy not only depends on the availability of the natural resources, and location of the country but also on the energy supply (Sasana and Ghozali, 2017). As energy occupies a central position in all spheres of life, its uninterrupted and efficient supply has become a key concern. Addressing this concern requires a rise in the proportion of renewables in the total energy mix (United Nations, 2015). According to the World Health Organization, energy and the fuel used by the residential sector account for 18% of worldwide carbon dioxide (CO2) emissions. Increased greenhouse gas emissions pose a significant threat to the environment and human health. Cleaner renewable energy technologies (solar, wind, geothermal, biogas, etc.) are expected to reduce CO2 emissions by 0.4 to 0.9 billion tones between 2010 and 2020, according to estimates (Nicholas et al. 2018).

For the past two decades, there has been a global call for renewable energy consumption in all countries throughout the world, particularly the most energy-intensive ones in Asia, the EU, and the Americas, as a means of supporting environmental sustainability. (Nguyen and Kakinaka, 2019, Brodny and Tutak, 2020). The push for steps to reduce the detrimental consequences of climate change is provided by projections about the worldwide depletion of fossil fuels and the new quest to migrate to greener energy usage (Maji et al., 2019). It has been stated that nonrenewable energy usage has more negative than positive environmental consequences, with CO2 emissions and other forms of environmental damage among them. These principles are diametrically opposed to those of environmental sustainability (Jamel and Derbali, 2016).

Many energy researchers (Nathaniel and Iheonu, 2019) have looked into the consequences of CO2 emissions as a metric of environmental sustainability and how they affect economic growth. Armeanu et al. (2017), for example, argue that Africa's lengthy reliance on conventional exhaustible energy supplies has exacerbated environmental challenges while impeding long-term economic progress. The impact of renewable energy usage on economic growth is a topic that has been extensively researched. The direction of causality between the two variables, in particular, was a significant area of study. They also emphasized that continuing to rely on fossil fuels to fulfil rising energy demand will only worsen environmental deterioration while failing to meet Africa's and Asia's growing energy demands (Said and Hammami, 2015).

More precisely, Nathaniel and Iheonu (2019) suggested that the continent's continued nonrenewable energy use will result in persistent and large CO2 emissions, posing a risk to long-term economic growth. Another line of inquiry in the energy debate frequently focuses solely on the long- or short-term relationship between renewable energy consumption and economic growth (Antonakakis et al., 2015). For example, Bhattacharya et al.

(2016) discovered that renewable energy consumption had a positive and significant impact on economic growth in the long run, whereas Alper and Oguz (2016) found the same result in the short term. Their arguments ignore CO2 emissions and instead focus on how increasing renewable energy use will boost renewable energy output, productivity, and GDP. Thus, the examination of CO2 as a measure of environmental sustainability and renewable energy use, and how each of them effects economic growth in Africa, appears to be independent within the existing literature.

Recent empirical and theoretical investigations on the subject, such as those by Wirth (2014), Cifor et al. (2015), Chang and Wang (2015), show that this is not the case (2017).

The importance of having an effective institutional quality was stressed by Mertzanis (2018) and Bhattacharya et al. (2017). Corruption must be controlled, democratic values must be respected, laws must be respected, and legislative power must be respected if a policy aimed at promoting the beneficial use of renewable energies is to work. Indeed, it's worth noting that the findings of many studies looking into the role of institutional quality in understanding the relationship between renewable energy and economic growth are largely mixed.

The lack of agreement could be due to discrepancies in the samples, procedures used, and the institutional variable chosen. Our research intends to contribute to this discussion by examining a set of institutional reforms that are acceptable. As previously said, the purpose of this paper is to investigate the role of institutions quality on the relationship between renewable energy consumption and economic growth in sub-Saharan Africa and to the knowledge of the authors, research on the combined effects of institution quality and renewable energy consumption on African economic growth.

Most African countries are still at a cross road when it comes to determining the right policies for ensuring the economy's long-term viability. Many African countries continue to rely heavily on nonrenewable energy, and the recent addition of renewable energy to the mix does not appear to be reducing emissions (Le et al., 2020). Numerous local characteristics in the research of these linkages is necessary to ensure an appropriate understanding of the nature of the relationship between renewable energy use, institution quality, and economic growth.

The rest of the paper is organised as follows. Section 2 briefly touches on literature with an emphasis on the topic. Section 3 discusses the model, data and estimation, techniques. In Section 4, we discuss empirical findings. In Section 5, we list our major conclusions and provide some policy suggestions.

2. Literature Review

2.1 Renewable Energy Consumption and Economic Growth

Studies like Omri et al. (2019), Aspergis and Payne (2009), Chen et al. (2007), and Ozturk (2010) have harmonised the relationship between economic growth and renewable energy consumption and other energy variables like electricity consumption, nuclear energy utilisation, total energy use, and electricity consumption into four testable hypotheses: growth hypothesis, conservation hypothesis, feedback hypothesis, and neutrality hypothesis.

According to the growth hypothesis, there is a unidirectional correlation extending from renewable energy usage to economic growth. This indicates that energy consumption is critical to any economy's growth and development. This massive impact could have a direct impact on the economy's productive components and key sectors, or it could have an indirect impact on human well-being and better living standards. As a result, our analysis could imply and support (Aspergis and Payne, 2009) that major energy sector shocks could have a detrimental impact on the economy. This concept has been criticized for failing to highlight the dynamics of renewable energy usage. Biomass energy, for example, is renewable, but over usage can result in significant environmental degradation, which has a detrimental impact on the economy.

The conservation hypothesis is diametrically opposed to the growth hypothesis. It claims that there is a one-way connection between economic growth and energy use. This also means that as overall economic activity and the value of total goods and services increase, people have more access to energy, as has been the case in the United States during the last two decades (Mohammadi and Ram, 2017). On the other hand, it implies that for a developing economy (such as Nigeria or Ghana) hampered by a lack of infrastructure and mismanagement of public resources, there may be gross inefficiencies leading to a drop in overall economic activity and, as a result, a drop in demand for goods and services, including energy consumption (Squalli. 2007).

The feedback hypothesis proposes that there is a feedback loop-like causal relationship between energy use and economic growth, as the name implies. While it is true that higher energy consumption may help to improve economic activity, it is equally true that increasing economic growth will boost people's economic power. They will be able to consume even more energy as a result of this. It is described by Squalli (2007) as a complimentary and bidirectional causation between the two.

Finally, the neutrality hypothesis indicates that economic development and energy use have no causal relationship. It considers energy consumption to be a minor part of overall economic growth, and so cannot have a significant impact on economic growth. Government initiatives aiming at increasing or decreasing energy consumption, according to the hypothesis, have no impact on economic growth. However, there may be exceptions to this hypothesis. For an economy like Nigeria, which relies on both domestic and international energy consumption to develop, positing a counterargument to this hypothesis and returning to the growth hypothesis would suffice.

2.2 Institution Quality and Economic growth

Institutions are critical to determining long-run economic growth (Hall and Jones, 1999; Rodrik et al. 2004) In general, how effective the government implements its policies are likely to enhance economic growth. Specifically, if handled effectively, government spending and expenditure will positively affect economic growth (Divino et al., 2020). Therefore, states with better institutional systems are bound to have a lower negative impact on growth than the weak institutional system of high impact on growth. More so, by effectively reduce spending on the non-development project tents to improve economic growth (Nirola and Sahu, 2019).

Political stability may likely be a factor deriving economic growth; since political leaders are more likely contest and are selected in political office in a politically stable environment and increase the likelihood of economic growth (Yu et al., 2020). Having this, political stability is pivotal for economic growth irrespective of the country settings (Uddin et al., 2017). Unlike the political instability, which is associated with the high uncertainty that investors may face concerning the security of property rights. Hence, a politically stable environment becomes necessary to persuade investors to invest since the property right is assured (Radu, 2015).

The rule of law can also indirectly influence economic growth by reducing carbon emissions and improving environmental quality, which restores investors' confidence to invest in considering the health condition (Muhammad and Long, 2021). Ajilore and Elumilade [2007] noted that corruption is cointegrated with economic growth in Nigeria with a significant negative unidirectional causality from corruption to economic growth. Ugur and Dasgupta (2011) concluded to a negative relationship between corruption and economic growth in poor and high-income countries. Moreover, Agostino et al. (2012) noted that corruption leads to lower GDP per capita growth.

Studies also found that governments seeking to promote energy infrastructure and encourage the use of renewable energy should adopt a policy that better coordinates financial development with targeted institutional improvement in new energy projects.

2.3 Renewable Energy Consumption, Institutions Quality and Economic Growth

One of the earliest studies on the causality of renewable energy and economic growth was carried out by Chein and Hu (2007), when they asserted that increased renewable energy has a positive association with economic efficiency, while increased consumption of conventional energy sources leads to decreased overall economic efficiency. In a recent study, Paramati, Sinha and Dogan (2017) analyzed the role of renewable energy on economic activates and CO2 emissions for the developing countries; using data from 19901 to 2012, they concluded that renewable energy has a positive and significant association with economic growth, while having a negative and adverse effect on CO2 emissions, hence they advocated employing more renewable energy in the current grid system to pace economic growth and to save the environment from degradation. Similarly, the same notion is adopted by Ref. U. Bulut, G. Muratoglu (2018), where the authors studied the impact of renewable energy consumption on GDP for Turkey for the period from 1990 to 2015. They found renewable energy did not affect GDP and asserted that the proportion of renewable energy was too small to have a significant impact on GDP. They further suggested increasing the share of renewable energy to decrease the deficit of energy trade.

Contrary to the above findings, another study analyzed the same notion for the same country and found a unidirectional causality between renewable energy and economic growth, while an autoregressive distributive lag (ARDL) test showed the negative association between renewable energy and economic growth O. Ocal, A. Aslan (2013). Another important study on the association between renewable energy and economic development was conducted using quarterly data from 1972 to 2011. It demonstrated that renewable energy has a feedback effect with economic growth, while the rest of the variables have a long-term association with each other. M. Shahbaz, N. Loganathan, M. Zeshan, K. Zaman (2015). While analyzing the energy scenario of Pakistan, another study found that energy consumption and economic growth have bidirectional causality; at the same time, energy consumption leads to environmental degradation. F.M. Mirza, A. Kanwal (2017). So, a sufficient proportion of energy sources should be renewable to enable smooth economic growth without compromising the environment. Apergis and Payne (2010) analyzed the relationship between renewable energy consumption and economic growth in the countries of Eurasia from 1992 to 2007. The result of the heterogeneous panel co-integration test reveals the long-term equilibrium between real GDP, capital formation, labor, and renewable energy consumption. The error correction model indicated a bidirectional association between economic growth and renewable energy consumption for the short and long-term periods. Most developing countries are rich in biogases, which are an important component of renewable energy. Developing countries can enhance the installed capacity of biogases to optimize their potential contribution in the energy mix S.S. Amjid, M.Q. Bilal, M.S. Nazir, A. Hussain (2011). In another study M. Kahia, M.S. Ben Aïssa, C. Lanouar (2017), of the Middle East and North Africa (MENA), net oil importing countries, results show a bi-directional causality between both kinds of energy source and economic growth, as well as between renewable and nonrenewable energy consumption that highlights their substitutability and interdependency. The results indicate that both types of energy source are essential for economic growth. Along with energy sources, the study also incorporated the regime type to analyze its impact on economic development for the of Sub-Saharan Africa for the period of 1980–2012 and found a long-term association between variables. Specifically, both sources are found to be significant for economic development, while nonrenewable energy is more salient for economic growth. Importantly, it was found that autocratic countries have less economic growth than democratic states. The role of political stability, regime type, and democracy cannot be ignored in the energy-economic growth nexus. Using data from 16 Sub- Saharan countries, Adams, Klobodu & Opoku (2016) analyzed the role of regime type and energy consumption along with trade openness on economic growth. Their results confirm that democracy moderates the relationship between energy consumption and economic growth.

Similarly, Adams, Klobodu & Opoku (2016) analyzed the impact of renewable and non-renewable energy regime type on economic growth for 30 Sub-Saharan countries for the period of 1980–2012. The results of various tests indicate a long-term association among variables and that the growth rate of democratic countries is higher than in autocratic countries. Therefore, most of the previous studies have been done in bits and pieces, and the role of institutional stability in economic growth is understudied. The present study addresses the issue and applies the production function to analyze the energy-institutional-economic growth nexus.

3 Methodology

3.1 Data and Variables

We use a panel data for a sample of 45 selected countries in Sub-Saharan Africa for the period 1990-2020. The choice of the period and countries was guided by data availability. The data were sourced from the World Development Indicator (WDI) and Worldwide Governance Indicators (WGI) databases. Table 1 is a summary of the measures of the data set used and their sources.

Table 1 Variables measurement

Variable	Symbol	Measurement	Source
Real GDP per capita growth	GDP	(GDP)/Population	World Bank (2022)
Renewable energy consumption	REC	Renewable energy consumption in percentage of total energy consumption	World Bank (2022)
Labour	L	percentage change in the logarithm of population	Penn World Table, Version 9
Capital stock	PK/HK	Gross fixed capital formation as a proxy of physical capital (PK) and secondary school enrolment rate as a proxy for human capital (HK)	Penn World Table, Version 9
Regulatory Quality	RQ	Institutional quality variables are binary dummies variables that are coded on a -2.5 to 2.5 scales, in a bid to enhance comparability all variables were normalize to mean 0 and component variance. In all cases, higher rankings mean better institutions[1]	World Governance Indicators (2022)
Rule of Law	RL		World Governance Indicators (2022)
Government Effectiveness	GE		World Governance Indicators (2022)
Control of Corruption	CC		World Governance Indicators (2022)
Political Stability	PS		World Governance Indicators (20)

3.2 Empirical Model Specification

Following an endogenous growth framework, the study specifies a model that best captures the effect of renewable energy consumption on economic growth. Given the growing empirical evidences supporting the positive effect of renewable energy consumption on economic growth (Bhattacharya et al., 2016; Alper & Oguz, 2016) we control for other factors considered as control variables that influence long run growth and generalize

[1] Many data sources can be used to document institutions quality. Among the main databases is the *Governance matters* project that started with the work of Kaufmann et al. (1999). The most recent methodology is described in Kaufman et al. (2009). The database reports six broad dimensions of governance for over 200 countries over the period 1996-2016. Five of the six dimensions are presented in table 1. The database also relies on experts' views. The six aggregate indexes are reported in standard normal units, ranging from approximately -2.5 to 2.5.

the specification of a growth equation that accounts for the effects of renewable energy consumption on economic growth. Thus, in deriving our empirical model for estimating this relationship for Sub-Saharan Africa, we posit that:

$$ln(Y_{it}) = \alpha + \beta ln(REC_{it}) + \boldsymbol{\lambda} ln(Z_{it}) + \eta_i + \varepsilon_{it} \quad (1)$$

Where $\ln(Y_{it})$ is the log of per capita GDP for country *i*, REC denotes renewable energy consumption, Z_{it} denotes vector of control variables which are labour and capital. To evaluate the effect of institutions quality on growth performance, we augment equation (1) with institutions quality variables as follows

$$ln(Y_{it}) = \alpha + \beta\ ln(REC_{it}) + \Phi ln(Institutions_{it}) + \boldsymbol{\lambda} ln(Z_{it}) + \eta_i + \varepsilon_{it} \quad (2)$$

Subsequently, we sequentially introduce interaction terms between renewable energy consumption and institutions into equation (2). This enables us to examine if the impact of renewable energy consumption on economic growth is conditional on the quality of institutions. In other words, the sign and significance of the coefficient of such interaction term will reveal whether the impact of renewable energy consumption on growth depends on the level of institutions quality. Incorporating this, we re-write equation (2) as follows:

$$ln(Y_{it}) = \alpha + \beta\ ln(REC_{it}) + \boldsymbol{\lambda} ln(Z_{it}) + [\gamma ln(Institutions_{it}) * \gamma ln(REC)] + \eta_i + \varepsilon_{it} \quad (3)$$

ε is the error term; β_i measures the relative effect of renewable energy consumption on growth, $\boldsymbol{\lambda}_i$ denotes a set of parameters measuring the relative effect of the control variables.

Equation (2) and (3) are the basis of estimating the relationship between economic growth and our measure of renewable energy consumption and institutions quality. The application of the pooled OLS estimation will be appropriate if the unobserved country-specific effects, η_i, are uncorrelated with the independent variables. On the other hand, the pooled OLS estimation will be unbiased and inefficient in a situation where a strong correlation exists between the unobserved individual effects, ηi, and the independent variables. In such a scenario, the fixed effect model will be more appropriate in estimating the parameters of the model. In a situation where the assumptions of the standard random effect hold given that the model does not in actual fact contain unobserved effects, in that case the pooled OLS will not only be efficient but the associated statistics will also be asymptotically valid. The study employs an AR (2) test for serial correlation in verifying for the absence of unobserved effect. This test's appropriateness is built on the assertion that the idiosyncratic errors are serially uncorrelated under the null H_0: $\delta^2\eta = 0$, when the independent variables are exogenous. Using this approach in detecting serial correlation amongst the idiosyncratic errors implies the existence of unobserved effect. The point in using panel data in a good number of research applications is to allow for the unobserved effect, ηi, to be randomly correlated with the set of independent variables, thereby necessitating the application of a fixed effect estimation procedure. The choice for employing either the fixed or random effect model estimation in the present study will be based on the outcome of the Hausman test result. The value of the Hausman test statistics will lead to either the acceptance or rejection of the null hypothesis. The null hypothesis will be rejected with a significant probability value of the Hausman test statistic and leads to the conclusion of the presence of fixed effects.

Following the works of Nathaniel and Iheonu, (2019, and Chang & Wang (2015), the study in addition uses a dynamic panel technique in addressing potential problems of endogeneity in the data adopting the procedures by Arrelano and Bover (1995) and Blundell and Bond (1998). This kind of dynamic panel framework is developed by the application of first difference transformation depicted by the following equation:

$$y_{i,t} - y_{i,t-1} = (\alpha - 1)\ y_{i,t-1} + \beta' X_{i,t} + \eta_i + \varepsilon_{i,t} \quad (4)$$

Where $y_{i,t} - y_{i,t-1}$ is real GDP per capita growth, $X_{i,t}$ denotes the set of independent variables including our measure of renewable energy consumption and institutions quality, ηi denotes the unobserved country-specific effect and $\varepsilon_{i,t}$ denotes the error term. We continue by rewriting equation (4) as:

$$y_{i,t} = \alpha'\ y_{i,t-1} + \beta' X_{i,t} + \eta_i + \varepsilon_{i,t} \quad (5)$$

Transforming equation (5) into first difference yields:

$$y_{i,t} - y_{i,t-1} = \alpha'\ [y_{i,t-1} - y_{i,t-2}] + \beta'\ [X_{i,t} - X_{i,t-1}] + [\varepsilon_{i,t} - \varepsilon_{i,t-1}] \quad (6)$$

It is clearly seen in equation (6) that the lagged difference in GDP per capita is correlated with the error term, which by implication of the potential endogeneity of the independent variables X, triggers the use of instrumental variables. In addressing this problem, the system difference estimator uses the lagged level of the independent variables as instruments in the assumption that the lagged level of the independent variables are weakly exogenous and that the error term is serially uncorrelated. Given that these conditions hold, we then apply the following moment conditions to calculate the difference estimator:

$$E\left|y_{i,t-s}\left(\varepsilon_{i,t} - \varepsilon_{i,t-1}\right)\right| = 0 \quad \text{for } s \geq 2; t = 3, \ldots, T \quad (7)$$

$$E\left|X_{i,t-s}\left(\varepsilon_{i,t} - \varepsilon_{i,t-1}\right)\right| = 0 \quad \text{for } s \geq 2; t = 3, \ldots, T \quad (8)$$

Blundell and Bond (1998) have shown that when the dependent variable and the independent are persistent over time, lagged levels of these variables can be used as instruments for the regression equation in differences. In the same way, for regression in levels, the lagged differences of the dependent variable and the explanatory variables can be used as valid instruments. Since persistence in the independent variable may severely affect the small sample and asymptotic property of the difference estimator, it is recommended that the difference estimator should be further combined with an estimator in levels to produce a system estimator.

A major benefit arising from the inclusion of a levels equation in a dynamic setting is that, it allows us to use information on cross-country heterogeneity, which is not possible by using the difference estimator alone. In practice, the use of lagged differences of the explanatory variables as instruments in an equation in levels is guaranteed under two conditions. First, the error term should be white noise. Secondly, there should exist no correlation between the difference in the explanatory variables and the error term. This therefore implies that the following stationary properties must hold:

$$E\left|y_{i,t} + {}_p\eta_i\right| = E\left|y_{i,t} + {}_g\eta_i\right| \ \&\ E\left|X_{i,t} + {}_p\eta_i\right| = E\left|X_{i,t} + {}_g\eta_i\right| \text{ for all p \& and g} \quad (9)$$

The additional moment's conditions for the regression in levels are:

$$E\left|\left(y_{i,t} - y_{i,t-s-1}\right)\left(\eta_i + \varepsilon_{i,t}\right)\right| = 0 \quad \text{for } s = 1 \quad (10)$$

$$E\left|\left(X_{i,t} - X_{i,t-s-1}\right)\left(\eta_i + \varepsilon_{i,t}\right)\right| = 0 \quad \text{for } s = 1 \quad (11)$$

Following the works of Blundell and Bond (1998) we employ two tests specification. We first use the Sargan test to verify for over identification restriction to test the validity of the endogenous instruments. Second, we test for second order serial correlation of the error term to verify whether the error term in the differenced equation model follows a process of first order.

4 Empirical Results and Discussion

Before estimating the specified growth equation, the summary statistics is presented to give a fair description of the link between renewable energy consumption, institution quality, and economic growth for the data set collected from a panel of 45 Sub-Saharan African countries over the period 1990-2020. The summary statistics for the entire sample of SSA countries is presented in table 2. From the summary statistics reported in table 2, GDP growth for the entire sample of SSA countries averaged around 4.3 %. Also, investment in physical capital (PK) averaged around 21.7% and investment in human capital (HK) and labour (L) averaged around 16.3% and 38.6% respectively. However, the extent of renewable energy consumption averaged around 24.4%. For the overall sample of SSA, the level of political stability PS average around 1.3%, and government effectiveness stood around -0.6%. This obviously revealed low level of government effectiveness as a component of institutional quality of the region. Regulatory quality and rule of law both averaged around -0.5% and control of corruption (cc) averaged around -0.6. This implies that for the entire sample countries of SSA, the control of corruption is low and hence the fight against corruption base to stimulate institution quality in enhancing growth is somehow not robust. Human capital development, measured as secondary school enrolment rate averaged around 11.3%, which is considered weak in the region compared to developed economies.

Moreover, the pair wise correlation matrix as reported in the lower segment of table 2 indicate positive relationship of all the independent variables with economic growth. There is no presence of multicollinearity as the correlation among the explanatory variable are fairly low.

Table 2 Summary Statistics for the overall sample of 45 SSA Countries

Variables	GDP	REC	PK	HK	L	RQ	RL	GE	CC	PS
Mean	4.3	24.4	21.7	11.3	38.6	-0.5	-0.5	-0.6	-0.6	1.3
Maximum	232.9	531.7	219.1	97.9	87.0	1.1	1.0	1.0	1.2	1.8
Minimum	-63.2	20.0	-2.4	3.9	47.7	-2.1	-2.2	-2.0	-1.9	-2.5
Std. Dev	3.2	3.6	18.3	23.6	10.4	0.6	0.7	0.6	0.6	0.9
Correlation Matrix										
GDP	1.000									
REC	0.29	1.000								
PK	0.36	0.63	1.000							
HK	0.25	0.20	0.14	1.000						
L	0.15	-0.12	0.13	-0.40	1.000					
RQ	0.11	-0.21	-0.09	0.50	-0.16	1.000				
RL	0.15	-0.03	0.06	0.59	-0.14	0.08	1.000			
GE	0.11	-0.09	0.01	0.62	-0.17	0.08	0.08	1.000		
CC	0.03	-0.03	0.01	0.5	-0.15	0.09	0.05	0.06	1.00	
PS	0.23	0.13	0.23	0.4	-0.08	0.61	0.08	0.64	0.62	1.00

4.1 Panel Unit Root Test Results

In order to analyze panel data, it is required to make the assumption that the data being used are stationary. The necessity of meeting the requirements of constant covariance, variance, and mean to support the excellence of the suggested parameters and models highlights the significance of the stationarity of data in panel data analysis. Therefore, before measuring the link between economic growth and the explanatory factors, it is important to take into account whether or not the data are stationary. Regressions using non-stationary variables can produce deceptive findings, displaying apparently significant connections even when the variables are independently created, as Phillips and Perron (1988) demonstrated. As the regression estimation is based on the presumption that the panel data are free from unit root, a unit root test can be used to determine whether or not the variables of interest are stationary. In this case, the test is also required. Levin, Lin, and Chu (2002), Im, Pesaran, and Shin (2003) panel unit root tests, as well as the ADF-Fisher (Dickey & Fuller, 1979) and PP-Fisher (Phillips & Perron, 1988), were all used in this work. Table 3 below has a summary of the findings.

Table 3 Unit root test results

Variable	**Test Statistics**			
	LLC	IPS	ADF	PP
GDP	-5.1(0.00)	-4.8(0.00)	54.6(0.00)	521.1(0.00)
REC	-7.9(0.00)	-9.0(0.00)	67.3(0.00)	429.0(0.00)
PK	10.7(0.00)	12.1(0.00)	74.1(0.00)	293.5(0.00)
HK	-6.5(0.00)	-8.7(0.00)	54.6(0.00)	631.7(0.00)
L	-4.0(0.00)	-5.5(0.00)	57.0(0.00)	813.8(0.00)
RQ	-4.1(0.00)	-4.4(0.00)	38.6(0.00)	112.2(0.00)
RL	-6.5(0.00)	-5.2(0.00)	41.1(0.00)	192.4(0.00)
GE	-8.3(0.00)	-5.8(0.00)	53.9(0.00)	171.7(0.00)
CC	-12.4(0.00)	-8.4(0.00)	39.0(0.00)	445.6(0.00)
PS	-6.5(0.00)	-7.3(0.00)	44.1(0.00)	412.2(0.000)

Notes: probabilities for Fisher tests are calculated using asymptotic Chi-square distribution. All other tests assume asymptotic normality. Values in parentheses are the probability values for the tests.

We use the Hausman test specification, as indicated previously in the methodology section, to choose between the fixed effects and the random effects model when establishing the level equations when presenting the panel regression findings. In contrast, the dynamic panel model's first difference estimate. utilizing the Stata command and the Arellano-Bond method. We consider the sample size of 45 nations from Sub-Saharan Africa to be representative of all SSA nations. Tables 4 and 5 present the findings.

The results of the Hausman specification test, which are shown in the lower part of Tables 4 and 5, consistently show that the unobserved effects of each unique country are unrelated to the independent variables, suggesting that the fixed effects model should be taken into consideration in comparison to the random effects model for the level regression of the regressions in levels. As a result, in our descriptions of the findings for the levels equation, we give the outcomes of the fixed effects model. The results of the Sargan tests, which are presented in the lower half of Tables 4 and 5, verify the validity of the instruments in all of the dynamic panel regressions for the dynamic model estimates, which are the ones we have used to assess our findings. Further evidence that there is no significant serial correlation issue in the residuals from the dynamic panel regressions is provided by the second order serial correlation tests presented in the lower segment of Tables 4 and 5.

Table 4 Panel Estimation Results for SSA without interaction terms

Variables	Estimators							
	FE	RE	GMM-Dynamic panel Model **(**first difference**)**					
	Model1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8
C	0.6328 (19.574)***	0.7025 (18.587)***	---------	---------	---------	---------	---------	---------
GDP-1	---------	---------	0.1397 (3.89)***	0.2227 (3.30)***	0.2214 (3.27)***	0.1351 (3.71)***	0.2013 (3.26)***	0.1412 (3.95)***
REC	0.2147 (8.49)***	0.1787 (10.33)***	0.1938 (6.18)***	0.1713 (8.39)***	0.1792 (10.70)**	0.1874 (5.95)*	0.1651 (8.46)*	0.1911 (6.11)*
PK	0.0201 (2.23)**	0.0112 (2.16)**	0.0133 (1.97)**	0.0361 (2.29)**	0.0792 (2.44)**	0.0252 (2.36)**	0.0301 (2.54)**	0.0352 (2.16)**
HK	2.3022 (8.55)***	2.1621 (8.39)***	3.0791 (8.52)***	2.3669 (8.71)***	2.1918 (8.51)***	3.1160 (8.63)***	2.2859 (8.45)***	3.0752 (8.51)***
L	2.829 (2.57)**	1.5483 (1.13)	1.2481 (5.826)**	1.5141 (2.23)**	0.0650 (2.58)*	2.0042 (2.42)**	1.0326 (2.24)**	2.0955 (-3.61)**

Variables	Estimators							
	FE	RE	GMM-Dynamic panel Model **(**first difference**)**					
	Model1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8
RQ				0.0220 (3.15)**	---------			
RL					0.0079 (2.49)**	---------		
GE						0.0291 (3.37)**	---------	
CC							0.0328 (4.79)***	---------
PS								0.0110 (1.44)
Observations	1395	1395	1395	1395	1395	1395	1395	1395
R^2	0.76	0.79	---------	---------	---------	---------	---------	---------
F-Statistics	53.819 (0.000)***	66.463 (0.000)***	---------	---------	---------	---------	---------	---------
χ2 - Hausman test	---------	12.361 (0.000)***	---------	---------	---------	---------	---------	---------
AR(2)	---------	---------	Z=-4.24 (0.663)	Z=-5.04 (0.537)	Z=-3.82 (0.622)	Z=-3.29 (0.804)	Z=-5.02 (0.713)	Z=-4.11 (0.617)
χ2 - Sargan Test	---------	---------	χ2 = 21.22 (0.355)	χ2 = 24.56 (0.325)	χ2 = 22.21 (0.6823)	χ2 = 20.35 (0.547)	χ2 = 25.56 (0.456)	χ2 = 22.84 (0.533)

Note ***, **, and * represents significant at the 1%, 5% and 10% levels respectively and ------ represents not applicable. The variables are expressed in log form and t–values are reported in parenthesis. The variables entering the Dynamic model are in first difference and their coefficients are interpreted as growth elasticities. Both the fixed effects and random effects models are in levels. The dynamic model is based on the Arellano-Bond Estimation procedure. FE = fixed effects, RE = random effect.

4.2 Analysis without Interaction Term

We begin our main analysis by examining the evidence based on the estimation of the baseline model with focus on the panel dynamic model which in reality captures the relative impact of the independent variables on GDP growth. The justification for this is that parameters estimated from both the fixed and random effects models are restricted to capturing only the level effects instead of the growth effects on GDP growth. The results are shown in table 4. Model 3 refers to the base specification of the dynamic panel without any institutional variable. The result shows that renewable energy consumption is associated with positive growth in real per capita GDP.

The coefficient of renewable energy consumption is 0.1938, implying that when renewable energy consumption shares increase by 10%, growth rate of real income increases by a margin of 0.19%. Undoubtedly, our result support the hypothesis that economies that uses more of renewable energy are likely to grow faster than others.

Models 4 to 8 report the results when institutional variables were sequentially introduced into the base model. The impact of renewable energy consumption in all the estimation is generally the same. There is overwhelming evidence of a positive and significant relationship between renewable energy consumption and economic growth.

With regards to the institutional quality variables, the dynamic panel regression results reveal that the coefficients of four of the measures of institutions quality (regulatory quality, rule of law, government effectiveness and control of corruption) have positive signs and statistically significant at the 1% and 5% levels (see table 4). It shows that improving the quality of institutions has a robust and positive impact on growth in Sub-Saharan Africa. This result is consistent with the findings by a wide range of studies on the role of institutions in enhancing growth performance (see e.g., Mertzanis 2018; Bhattacharya et al., 2017). However, the impact of the variable (control of corruption) on growth (0.0928) is relatively higher than the other measures. This result is consistent with the conventional understanding that tackling the prevalence of corruption is important for achieving higher economic performance, especially in the Sub-Saharan Africa region.

Turning to the control variables, the evidence in Table 4 indicates that they are generally satisfactory in their respective coefficients. In particular, the results indicate that investment in physical capital is positive and statistically significant in influencing growth as expected. Similarly, investment in human capital is also shown to be positive and robustly significant to growth in line with the endogenous growth theory. Taken together, the results imply that investments in both physical and human capital are crucial for economic growth. However, it is worth noting that the impact of human capital on growth (2.3022) is higher than that of investment in physical capital (which is about 0.0201), emphasizing the importance of the former over the later on growth.

Labour bears the expected positive and significant coefficient. One possible explanation for this result is that higher labour force participation rate is likely to correlates positively with GDP growth which is an important input in any growth matrix. In general, the growth of labour force enters the dynamic growth equation with a positive sign and significant at the 1% level, for the entire sample of SSA countries signifying that an increase in the labour force by 10%will induce economic growth by 2.829%.

Table 5 Panel Estimation Results for SSA with interaction terms

Variables	Estimators							
	FE	RE	GMM-Dynamic panel Model (first difference)					
	Model1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8
C	0.6328 (19.574)***	0.7025 (18.587)***	---------	---------	---------	---------	---------	---------
GDP-1	---------	---------	0.1397 (3.89)***	0.3672 (7.34)***	0.3462 (8.354)***	0.3922 (4.42)***	0.2620 (8.63)***	0.1725 (6.66)***
REC	0.0147 (8.49)*	0.0787 (10.33)*	0.0938 (6.18)*	0.0142 (11.50)**	0.0626 (7.36)*	0.1421 (10.63)*	0.0652 (5.37)*	0.053 (6.78)*
PK	0.0201 (2.23)**	0.0112 (2.16)**	0.0133 (1.97)**	0.0412 (3.52)**	0.0822 (3.78)**	0.0191 (4.27)**	0.0792 (3.33)**	0.0426 (6.256)**
HK	2.3022 (8.55)*	2.1621 (8.39)*	3.0791 (8.52)*	1.8215 (12.43)**	2.232 (8.07)*	3.8372 (8.256)*	3.2521 (5.937)*	3.8262 (7.352)*
L	2.829 (2.57)**	1.5483 (1.13)	1.2481 (5.826)**	0.9362 (3.331)**	0.0902 (2.74)*	2.6320 (2.47)**	0.9376 (6.763)**	3.6725 (9.722)*
RQ*REC				0.142 (2.367)**	---------			
RL*REC					0.0415 (3.82)**	---------		
GE*REC						0.0511 (2.63)**	---------	
CC*REC							0.0522 (4.25)***	---------
PS*REC								0.0052 (0.562)
Observations	1395	1395	1395	1395	1395	1395	1395	1395
R^2	0.76	0.79	---------	---------	---------	---------	---------	---------
F-Statistics	53.819 (0.000)***	66.463 (0.000)***	---------	---------	---------	---------	---------	---------
χ2 - Hausman test	---------	χ2 = 12.361 (0.000)***	---------	---------	---------	---------	---------	---------
AR(2)	---------	---------	Z=-4.24 (0.733)	Z=-5.83 (0.632)	Z=-5.73 (0.617)	Z=-4.27 (0.805)	Z=-5.00 (0.634)	Z=-3.63 (0.719)
χ2 - Sargan Test	---------	---------	χ2 = 29.42 (0.637)	χ2 = 23.76 (0.634)	χ2 = 31.42 (0.437)	χ2 = 22.35 (0.744)	χ2 = 23.84 (0.674)	χ2 = 27.33 (0.537)

Note ***, **, and * represents significant at the 1%, 5% and 10% levels respectively and ------ represents not applicable. The variables are expressed in log form and t–values are reported in parenthesis. The variables entering the Dynamic model are in first difference and their coefficients are interpreted as growth elasticities. Both the fixed effects and random effects models are in levels. The dynamic model is based on the Arellano-Bond Estimation procedure. FE = fixed effects, RE = random effect.

4.3 Analysis with Interaction Term

Introducing the interaction terms (see table 5) does not alter the results with regards to the signs and statistical significance of the control variables. Consistent with table 4, the impact of renewable energy consumption on growth is still positive and statistically different from zero with very small marginal effects.

Interestingly, the interaction of renewable energy consumption with regulatory quality, rule of law, government effectiveness and control of corruption generates robust and high marginal positive effects on growth. This simply implies that these institutional factors are connected to the effectiveness of renewable energy usage on growth in Sub-Saharan Africa. Practically, the result confirms that in the absence of good institutions, renewable energy use alone would have very small impact on growth. In effect, improving the quality of institutions, especially as it relates to corruption control, quality of renewable energy policy formulation and implementation, the credibility of government's commitment to renewable energy policies as well as the quality of contract enforcement and protection of property rights, is important. Corruption, for instance, reduces private investment owing to higher costs and increasing uncertainty on the part of the investor. By these results, institutional quality and renewable energy usage are complementary in the growth process of countries in Sub-San Africa. However, we observed that the impacts are generally small which might reflect the fact that the qualities of institutions in Sub-Saharan Africa are too weak.

5 Conclusions and Policy Recommendation

5.1 Conclusions

In this study the broad objective has been to investigate the link between renewable energy consumption and economic growth. Specifically, the paper examines two major issues. Firstly, the empirical analysis analyzed the effect of renewable energy consumption on economic growth in Sub-Saharan Africa. Secondly, to further enrich the debate the empirical analysis investigates the interacting role of institution quality with renewable energy consumption on economic growth in SSA countries. The paper was empirically examined using panel data framework for 45 selected countries in SSA. To avoid omitted variable bias, we controlled for core growth variables including investment in physical capital, human capital and labour force participation rate.

OLS results based on fixed and random effects and Generalized Method of Moments system (GMM-Panel Dynamic) estimators show that investment in physical capital, human capital and labour force growth are important factors for growth performance in SSA. Most importantly, we found that renewable energy consumption alone has a weak positive impact on growth in SSA. Further estimations confirm that for renewable energy usage to have a significant positive impact on growth, the qualities of domestic institutions are important. In specific, we found that the positive impact of renewable energy usage on economic growth is conditional on the quality of institutions, especially as it relates to control of corruption, regulatory quality, rule of law, quality of renewable energy policy formulation and implementation, the credibility of government's commitment to clean energy and policies as well as the quality of contract enforcement and protection of property rights.

Since the simultaneous interaction of institutions quality indicators and renewable energy consumption has significant positive effects on growth in the SSA countries, we therefore contend that the complimentary role of renewable energy use and institutions quality is good for growth and the policy direction is that strong institution quality may be necessary for accelerating growth in SSA.

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