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Renewable Energy and Inclusive Economic Development: An African Case Study

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ABSTRACT

Climate change constitutes a major challenge to economic growth and development across the globe as it negatively affects most sectors of the economy. Hence, there has been a global clamour for countries to invest in climate change mitigations. In developing regions like Africa, however, there are high resource limitations, and as such, there is a general opinion that funding climate change mitigation will have a huge opportunity cost of low investment in other development infrastructures, with the likelihood of decreasing economic development. On this premise, this study investigates the impact of renewable energy consumption and output on economic development in Africa. The study employed panel data analysis estimated using the System Generalised Method of Moments for a sample of 43 Sub-Saharan African countries. The results show that an increased share of renewable electricity in total electricity production increased significantly and contributed positively to economic development in Africa. Also, the ratio of renewable electricity to the total electricity consumed had a positive but insignificant effect on economic development. The study thus concludes that an increase in renewable electricity production and consumption does not only mitigate climate change but could also contribute marginally to the economic growth and development of African economies.

Keywords

Renewable Energy;
Economic Development;
Climate Change;
Africa

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1. Introduction

Climate change constitutes a major challenge to economic growth and development across the globe as it negatively affects most sectors of the economy. Hence, for more than two decades now, renewable energy has been urged to be used at universal and regional levels. The 26th United Nations Climate Change Conference, held in Glasgow in 2021, Cop 26, recognized that the consumption of coal, oil, and gas are the main drivers of global warming; It was emphasized that coal is responsible for more than 40% of annual carbon emissions.

Due to this, the 7th goal of the 2030 Agenda for Sustainable Development Goals (SDG) aims to guarantee universal access to affordable, dependable, sustainable, and modern energy. The 8th goal aims to encourage full and productive employment, decent work for all, and sustainable and inclusive economic growth, while the 13th goal calls for taking immediate action to prevent climate change and its effects [1].

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While the relevance of renewable energy is recognized in the global space [2–6]. its adoption across countries depends on funding capacity, pressure from the increasing demand for power, limited renewable energy technology development, and costs already incurred in acquiring non-renewable energy production equipment, the political will to implement it amongst others [7–10]. These may explain why Africa lags behind other continents in renewable energy adoption.

The International Energy Agency posits that achieving full access to modern energy in Africa by 2030 required an investment of USD 25 billion per year[7], which is equal to around a quarter of total energy investment in Africa prior to the pandemic and around USD 2.5 billion per year of investment in clean cookstoves and other end-use equipment. Meanwhile, the average cost of electricity generation has been higher in Sub-Saharan Africa (SSA), due to the subsistent livelihood that results in a small size of electricity markets and hence limited economies of scale—as well as by electricity tariffs that are too low to recover utilities' costs [11].

Furthermore, Africa faces huge resource constraints in advancing renewable energy as it is increasingly in need of capital for competing infrastructure projects beyond power infrastructure as well as other development needs. For example, Holtz and Heitzig posit that, in order to close Africa's electricity infrastructure gap, annual investment in infrastructure must double between 2015 and 2025, amounting to USD 150 billion by 2025[12].

Meanwhile, in 2018, the African Development Bank estimated that the continent's infrastructure needs – including power and water systems as well as new roads and railways – amounted to between $130billion and $170 billion yearly, with a financing gap in the range of $67.6 billion to $107.5 billion [13]. Baker and co-authors highlight the struggle over competing energy visions, infrastructures, and political agendas and generate insights into the governance and financing of clean energy transitions in South Africa [14].

Despite these challenges, Africa is better suited to expand its energy generation from renewable sources. Projections show that renewable energy cost is decreasing and is envisaged to compete favourably with conventional sources of energy soon. Also, Africa is a potential market for electricity, since only 48.4% of sub-Saharan Africans had access to electricity in 2020 [15]. This translates to a huge demand for electricity in SSA, especially in the context of an increasingly global digital economy. Africa also has a relatively huge potential for renewable energy generation thanks to its geographical location which gives it high access to solar, wind, and bio-degradable energy sources amongst others.

Research by McKinsey established that Africa's potential energy generation capacity, including solar, stands at 10 terawatts [16]. According to the World Economic Forum, since 2013, Africa's installed renewable energy capacity has expanded by more than 24 GW; with prospects of an extra 27.3 EJ by 2050 compared to the current 1.8 EJ [17].In Addition, Africa is home to some of the best renewable energy resources on the planet and abundant mineral resources, many of which are critical to numerous clean energy technologies [7].

Considering these prospects, and in agreement with the urgent need to completely adapt to climate-smart practices such as the use of renewable energy, it is imperative to understand how renewable energy production and use are affecting economic development in Africa. The understanding of how renewable energy contributes to growth and development is much more explicit in Western climes. There, several empirical studies abound, that have examined the connection between REC/output and industrial growth [9,18,19], economic growth [20–24] , both at regional and country-specific levels.

Conversely, most empirical evidence in Africa examines the association between renewable energy and economic growth, without much connection to economic development especially when proxied with the Human Development Index, captures the general well-being of citizens of a country or region in terms of general education, health, and per-capita income. It is therefore a more inclusive measure of development. To close this gap, this study was conducted to ascertain the impact of the production and use of renewable energy on the economic development of Sub-Saharan African countries.

This study contributes to the existing stock of literature in 4 key ways. First, it examines the relationship between renewable energy and economic development in SSA, which deviates from the existing researched relationship between renewable energy and economic growth. Second, it employs a world-acclaimed dynamic panel data analysis – the System General Method of Moments (S-GMM). Blundell & Bond posit that the S-GMM dynamic panel estimator method is able to correct time invariant country specific effect, omitted variable bias, measurement error and endogeneity problem [25,26].

As a control measure, the study equally evaluates the relationship between renewable energy and per capita GDP which is perceived as a welfare indicator and roughly reflects individual income levels. Finally, rather than simply using REC or output as some studies did, this study employs the share of renewable electricity output and consumption to total electricity output and consumption respectively, to have a more meaningful picture of this relationship.

2. Literature Review

Renewable energy and its capacity to drive inclusive development have been explored by scholars in various regards. However, in the context of Africa specifically, few studies have argued in favour of the role of clean energy transition, vis-à-vis renewable energy, on critical metrics of growth and development. While some studies have argued that the effect differs across countries [24,27–31], others have rather adopted a holistic argument and emphasized the need for renewable energy in fostering sustainable development.

The relative lack of consensus on the subject matter makes it imperative to further divulge the capacity of clean energy to drive inclusive growth and development across Africa. To sufficiently conceptualize renewable energy in the light of economic development, this study considered a wide range of literature on economic growth, since economic growth has been a prerequisite for development. Essentially, this section first discusses the key competing theories; and then documents existing studies on renewable energy as a catalyst for economic growth and development, starting from a more generalised perspective to a more specific focus on Africa, whilst also accounting for institutional factors.

2.1 Theoretical Perspectives

Four essential hypothetical underpinnings associated with renewable energy, energy consumption, and economic growth and by extension – development, have been sufficiently documented in existing literature [21,32–35]. These hypotheses provide various dimensions to characterize the nexus between renewable energy and economic growth. They include the Feedback hypothesis, Neutrality hypothesis, Growth hypothesis, and Conservation hypothesis.

The Growth hypothesis suggests that energy consumption is a key factor in economic expansion. The growth hypothesis has empirical evidence since there is unidirectional causality linking economic growth and energy use. This significant impact may have an immediate effect on the key economic drivers or may have an inverse impact on people's well-being and living standards. In this situation, initiatives to conserve energy that reduce energy use will have a detrimental effect on economic expansion and development. A different way to look at this relationship (energy consumption and economic growth/ development) is implied by the feedback hypothesis.

According to the Feedback hypothesis, energy use and economic expansion are mutually beneficial. It creates a connection between energy use and economic growth. In other words, real GDP and energy use are causally related with each other. Although this hypothesis admits that energy use is a major contributor to economic growth, it also contends that expanding economic opportunities brought on by that growth are essential to maintaining energy consumption. As a result, it is believed that there is a reciprocal and bidirectional relationship between GDP growth and energy use. The Conservation hypothesis presents a departure from this concept.

While the conservation hypothesis posits that conserving energy does not prevent economic growth. This hypothesis is consolidated if there is a one-way relationship between economic growth and energy use. As it views economic expansion as a stimulus for energy use, this hypothesis differs from the Growth hypothesis. This suggests that rising GDP has a knock-on effect on energy use.

Finally, the neutrality hypothesis also holds that there is typically no causal link between energy use and economic growth. It further asserts that energy conservation has little impact on economic growth. This hypothesis suggests that policies targeted toward increasing or contracting energy consumption essentially do not affect GDP growth.

The increasing evidence of an inverse or negative relationship between energy use and economic growth seems to suggest a fifth hypothesis – the pessimistic hypothesis. It is worth noting however that this goes contrary to the existing stock of literature on the direction of causality between energy use and economic growth/development.

2.2 Renewable Energy as an Engine of Economic Growth & Development

In examining the relevance of renewable energy on economic conditions in OECD countries, Inglesi-Lotz [36] adopted a pooled regression technique and fixed effects models on a sample of selected OECD countries from 1990 to 2010. The findings of the study demonstrated a positive and significant relationship between REC (or its contribution to overall energy output) and economic growth; supporting the growth hypothesis. However, an evident limitation of his study was that it failed to account for cross-sectional heterogeneity in the sample.

Based on this limitation, Dogan et al., [27] have looked into the effect of using renewable energy on economic growth, employing the same data sets as Inglesi-Lotz. Their study essentially addressed the issue of heterogeneity which was inherent in the work of Inglesi-Lotz, and found significant divergence. Employing a quantile regression methodology, they found an asymmetric effect for a category of five countries based on quantiles. They argued that economic growth is positively impacted for countries in the lower and lower-middle income brackets (validating the growth hypothesis), whilst an inverse relationship was the case for countries in the middle bracket, high-middle quartile, and higher bracket – validating the pessimistic hypothesis.

A clear case for emerging markets (BRICS) was presented Akram et al., [28]. They investigated the effects of energy efficiency and renewable energy on economic growth. REC was found to significantly lower the economic growth in BRICS economies, but the negative influence was more robust at the upper quantiles. They also validated the Feedback Hypothesis with inference from the heterogeneous panel causality test, between energy consumption and economic growth.

Similarly, For the Black Sea and Balkan nations, Koçak and Arkgüneşi [31] also investigated the relationship between renewable energy and economic growth. The findings from heterogeneous panel causality estimation methodologies support the Growth hypothesis in Bulgaria, Russia, Macedonia, Greece, and Ukraine. Similar to this, the Neutrality theory was discovered in Turkey, whereas the Feedback hypothesis was visible in Albania, Georgia, and Romania. Overall, their study shows that REC had a significant impact on economic growth for all countries considered, which is in tandem with the growth hypothesis.

A more robust study was conducted by Chen et al. [29] for a sample of 103 countries. Consumption of renewable energy and economic growth were found to be positively and significantly correlated in both developing and OECD nations. However, a significant effect was not shown for developed countries. The threshold model also reflects that the relationship between REC and economic growth was dependent on the amount of renewable energy that was being used. REC was shown to harm economic growth if it falls below a specific threshold in developing nations, therefore suggesting a pessimistic hypothesis in this case.

Given that these previous studies focused on the linear relationship between REC and economic growth, Wang and Wang [37]developed three-panel threshold models to investigate the non-linear relationship between REC and economic growth in OECD countries. Empirical findings from their study demonstrated a positive effect of REC on economic growth in which the relationship changes as the threshold value is increased thereby confirming the existence of a non-linear relationship.

Similarly, Baz et al., [38] employed non-linear (ARDL) and asymmetric causality approaches to examine the asymmetric impact of fossil fuel and REC on economic growth in Pakistan. The result of their study supports asymmetric and nonlinear co-integration between fossil fuel, REC, and economic growth. Positive shocks to economic growth were found to have an asymmetric feedback causal relationship with REC. Hence, validating the feedback hypothesis.

More so, Kamiri et al., [39] employed bound tests and asymmetric methodologies in establishing empirical perspectives on REC, CO_2 emissions and GDP, using Iran as a case study. The crux of their study was that in the long run, increased economic growth per capita will ultimately be propelled by REC and GHG emissions. They also found that in the long run, a reduction in CO_2 insignificantly impacts economic growth per capita. From the test for asymmetry, they found that in the short run, carbon emission reduction and REC do not necessarily impact economic growth.

In the context of development, from a global perspective, the work of Amer, [40] provided insights into the capacity of REC to drive human development. Employing a panel cointegration technique and GMM methodologies, the research argued that the capacity of REC to deplete carbon emissions was insignificant across all sub-samples. Similarly, REC on human capital development was also found to be insignificant across all samples except for low-income countries.

A more concentrated exposé about the OECD countries for the period 2004–2015, was carried out by Soukiazis et al., [41]. Adopting a simultaneous equation parametric approach, the paper shows the contribution of renewable energy in fostering sustainable development. Specifically, it found that physical and human capital, coupled with REC, are crucial determinants of sustainable development. They further posited that research and development, country-level development trajectories, and human capital are essential determinants of REC. This aligns with the feedback hypothesis, as is the case with Sasmaz et al. [42] discussed below.

This is further in tandem with the works of Sasmaz et al. [42] who investigated human development and renewable energy across 28 OECD nations from 1990–2017. Estimating a panel cointegration and testing for causality, they found a positive relationship between REC and human development, proxied by Human Development Index (HDI). Similar to the previous literature, they discovered a bi-directional causal relation between HDI and renewable energy. From a policy perspective, they emphasized the need for policymakers to scale up investment in renewable energy, via the private sector, as it was evidenced to be a driver of human development.

2.3 Empirical Evidence from Africa

For Africa, Numerous studies have demonstrated an existing link between the use of renewable energy and economic growth and development. Particularly, the works of İnal et al. [20], whose study focused on demystifying the contribution of renewable energy and CO_2 emissions on economic growth, employed a bootstrap procedure, on a sample of oil-producing African nations. Their studies gave validity to the Neutrality Hypothesis, as renewable energy was evidenced to be a positive and significant driver of economic growth.

Synonymously, Qudrat-Ullah & Nevo [21], reemphasized the relevance of REC in fostering African economic growth when they employed the SGMM parametric technique in establishing both long-run and short-run dynamic positive effects of renewable energy on economic growth. They further posited that emission reduction is not sine qua nor in Africa's path to addressing environmental sustainability concerns, as CO_2 emissions turned out insignificant.

In the same vein, accounting for growth disparities across Africa, Adekoya et al., [24] examined the effect of REC on economic growth, whilst accounting for institutional reforms and technological factors. Employing the Augmented Mean Group technique, they discovered that REC had a slight but positive link with economic growth in upper- and lower-middle-income nations. The reverse was the case with lower-income countries as renewable energy demonstrated a negative relationship with economic growth.

In a different study, Brini [22] studied the relationship between the usage of renewable and non-renewable energy, economic growth, and climate change for a sample of 16 sub-Saharan African nations. utilizing the distributed lag model with panel mean group autoregression, Granger test for causality, and Panel PMG-ARDL model, the research found long-run convergence amongst the variables and further opined that REC is critical to addressing climate change, whilst economic growth premised on non-renewable energy was proven to be harmful in the long run.

A more specific study was carried out by Adebayo, et al., [23,43], who examined the nexus between CO_2 emissions, renewable energy, coal consumption, and economic growth trajectories in South Africa. Adopting the dynamic OLS and FMOLS methods, they argued that the trend in South Africa's economic growth is unclean. They further reemphasized the need for policymakers to ensure an energy transition from the traditional dependence on fossil fuel, to renewable energy which fosters clean economic growth and ecological preservation.

Similarly, Ibrahiem [43] found a similar relationship when he investigated renewable electricity consumption, economic growth, and Foreign Direct Investment (FDI). Leveraging Author Regressive Distributive Lag (ARDL) bounds test procedure, long-run convergence amongst the variables was established, whilst accounting for both unidirectional (FDI and economic growth) and bidirectional (economic growth and renewable electricity consumption) causality.

The majority of empirical literature in Africa upholds the feedback hypothesis that demonstrates a bi-directional causality between renewable energy and economic growth [20,21,23,43]. Meanwhile, Adekoya et al., [24] show that in upper- and lower-middle-income nations validate the growth hypothesis while lower-income countries validated the pessimistic hypothesis. And Brini's [22] findings inferred a growth hypothesis.

Empirical Evidence that examines the relationship between energy use and economic growth abound; fewer studies focus on the relationship between renewable energy and economic growth, and even fewer such studies concentrate on Africa. This study goes further to analyze the relationship between renewable energy (using two proxies) and economic development with many more African countries and a more robust methodology – the S-GMM.

The S-GMM, according to Soto [44] has a lower bias and higher efficiency than all the other estimators analyzed, including the standard first-differences GMM. The S-GMM is equally better than the other panel estimators that were employed previously such as the pooled regression technique, panel fixed effects models, Panel PMG-ARDL, which fail to cater for cross-sectional heterogeneity.

3. Methodology and Data

This section details the methodology and data description of the study. The methodology explains how the objective of the study shall be investigated and why. While the Data section defines the scope, and sources of the data used.

3.1 Methodology

Following Arbex and Perobelli [45], Mahmoodi and Mahmoodi [46] and Karimi et al.[39], this study extends the traditional neoclassical Cobb–Douglas production function by integrating REC proxied by Renewable electricity share of total electricity output (RESTEO); Renewable electricity share of the total electricity consumed (RESTEC). The key dependent variable will be the Human Development index which represents a composite index of life expectancy, mean and expected years of schooling and GDP percapita of a country. The production function is therefore given as follows:

$$Y_t = AK_t^{\varnothing} L_t^{\pi} E_t^{\rho} \tag{1}$$

Where Y_t is the outcome variable, $K_t^{\varnothing}$ is capital, L_t^{π} is Labor, E_t^{ρ} is energy consumption and A is the parameter of technology, t represents the period $(t = 1.., T_i)$, while $\varnothing, \pi$ and ρ are parameters to be estimated.

The study covers 43 SSA countries with annual data from 2008 to 2015, The study employed a panel data analytic method, and the model of Eq. (1) is transformed to:

$$Y_{it} = A_{it} K_{it}^{\varnothing} L_{it}^{\pi} E_{it}^{\rho} \tag{2}$$

With log-linearisation and the addition of other control variables adapted from the empirical works of Wang et al [47], the panel Cobb–Douglas production function stated in Eq. (2) becomes:

$$\begin{aligned} Y_{it} &= \alpha_i Y_{it-1} + \varnothing_{it} K_{it} + \pi_{it} L_{it} + \rho_i E_{it} + \delta_{it} X_{it} \\ &\quad + \theta_i + u_t + \varepsilon_{it} \end{aligned} \tag{3}$$

Where i indicates the country $(i = 1.., N)$, Y_{it} is the outcome variable – economic development, proxied with HDI; Y_{it-1} is the one-period lag of the outcome variable in country i, E_{it} represents RESTEC and RESTEO in country i, while X_{it} represents a vector of control variables. $, \varnothing, \pi, \rho, \delta,$ and α are the parameters and vectors of parameters to be estimated, θ_i represents country-specific effects, u_t represents period-specific effects and, ε_{it} is the error term. The control variables are based on theoretical and empirical inference of the determinants of economic development. They include government effectiveness, private Sector credit (% GDP), inflation (CPI), real interest rate, exports (% GDP), FDI (% GDP) and Capital formation (% GDP).

The model was estimated using the S-GMM initiated by Hotz et al., [48]. The superiority of the S-GMM estimator over other panel estimators has been sufficiently validated in the literature [25,26,44]. GMM is globally revered in part due to its ability to overcome endogeneity issues and cater for omitted variable concerns thus, improving the accuracy of the parameter estimates [21,49]. Soto [44], employs Monte Carlo simulations to show that the S-GMM estimator has a lower bias and higher efficiency than all the other estimators analysed, including the standard first-differences GMM estimator in lower sample sizes (less than 100), which is common in cross country studies such as this. The S-GMM estimator combines a system with a first-differences regression with a level regression such that variables in differences are instrumented with the lags of their levels and variables in levels are instrumented with the lags of their differences [50,51].

Uddin et al. [51] further posit that, although the level of predetermined variables correlates with the country-specific fixed effect, in the S-GMM, the variances are not correlated. Again, Roodman [52] states that S-GMM is more advantageous relative to the difference GMM, as the later tends to amplify the gaps in unbalanced panel data. This makes S-GMM more suitable for the analysis of this unbalanced data set.

3.2 Data

The study employed a panel of 43 countries with data from 2008 to 2015. The study was limited to 2015 due to the unavailability of data on some of the key variables

(RESTEO, RESTEC) beyond 2015. However, the number of time series and cross-sectional observations employed offered enough degrees of freedom for the methodology employed to deliver robust and reliable results.

The 43 countries covered are Angola, Benin, Botswana, Burkina Faso, Burundi, Cabo Verde, Cameroon, Central African Republic, Chad, Comoros, Democratic Republic of Congo, Congo Republic, Cote d'Ivoire, Equatorial Guinea, Eritrea, Gabon, The Gambia, Ghana, Guinea, Guinea-Bissau, Kenya, Lesotho, Madagascar, Malawi, Mali, Mauritania, Mauritius, Mozambique, Namibia, Niger, Nigeria, Rwanda, Sao Tome and Principe, Senegal, Seychelles, Sierra Leone, South Africa, Sudan, Tanzania, Togo, Uganda, Zambia and Zimbabwe. The summary statistics of the data are shown below.

From the available data, there were some countries without a record of renewable electricity output for some years. While Lesotho recorded 100% of its electricity output from renewable sources during the study period, Seychelles recorded the least renewable electricity share of the total electricity consumed in 2008 with 0.38%. The correlation matrix in Table 2, shows a low average relationship between the independent variables but a relatively higher relationship between the independent variables and HDI, which is the dependent variable.

Table 1: Descriptive analysis of the data.

Description	**Mean**	**Std. Dev.**	**Min**	**Max**
HDI	0.51	0.092	0.314	0.789
GDP Percapita (current US$)	2332.3	3180.1	305.5	16438.64
Renewable electricity output (KWh)	2160.6	3509.2	0	17207
RESTEO (% of total electricity output)	44.29	36.63	0	100
Renewable electricity consumed (KWh)	23156.2	611614	28.87	4320767
RESTEC (% of total final energy consumed)	63.66	26.21	0.38	97.02
Exports (% GDP)	31.23	18.9	0.67	107.99
Private Sector Credit (% GDP)	21.38	23.38	2.65	129.17
Capital formation (% GDP)	24.9	9.93	5.13	79.4
Inflation (CPI)	6.78	6.5	-4.3	36.97
Real Interest Rate	8.13	10.2	-34.7	50.76
Government Effectiveness	0.333	7.2	-1.8	52.6
Labour force participation	66.44	11.56	42.6	87.4

Table 2: Pairwise correlations matrix of the variables.

	HDI	**RECTEO**	**RECTEC**	**GE**	**PS**	**PSC**	**EX**	**GFCF**	**RI**	**LF**
HDI	1.00									
RECTEO	-0.19	1.00								
RECTEC	-0.64	0.42	1.00							
GE	0.16	0.08	-0.13	1.00						
PS	0.31	0.06	-0.33	-0.11	1.00					
PSC	0.63	-0.25	-0.54	0.02	0.31	1.00				
EX	0.44	-0.12	-0.59	0.02	0.34	0.13	1.00			
GFCF	0.21	0.03	-0.24	-0.08	0.12	0.03	0.144	1.00		
RI	0.04	0.10	0.11	-0.17	0.01	-0.14	-0.12	0.03	1.00	
LF	-0.38	0.37	0.57	0.05	0.10	-0.23	-0.29	-0.10	0.13	1.00

where: GE represents government Effectiveness; PS is political stability; PSC is private Sector credit (% GDP), EX is Exports (% GDP), GFCF is Gross fixed Capital formation (% GDP), CPI stands for Inflation (CPI); RI for real Interest Rate; and LF for labour force participation as a proportion of the population.

Table 3: Expected Signs of the Variables

Variable	Expected Sign	Rationale
HDI (-1)	+	HDI in the previous year improves development in the current year, ceteris paribus
GDP Per capita (-1)	+	GDP per capita in the previous year improves GDP per capita in the current year, ceteris paribus
Renewable electricity share of total electricity output (%)	+	It is usually relatively more affordable and effective and so should increase production growth
Renewable electricity share of the total electricity consumed (%)	+	It is usually relatively more affordable and effective and so should increase production growth
Government Effectiveness	+	A more effective government reduces government bottlenecks and therefore provides an enabling environment for production
Private Sector Credit (% GDP)	+	Private sector credit promotes firms, increases unemployment and improves development
Labour Force (%)	+	Endogenous growth theories and several other growth theories emphasize the relevance of human capital in growth and development
Real Interest rate	-	The lower the interest rate, the higher the ability to take loans, invest, employ, and produce
Exports (% GDP)	+	Higher exports increase government revenue and improve prosperity via the multiplier effect.
Capital formation (% GDP)	+	As a proxy of investment, it directly translates to higher production and development.
Political Stability	+	A political stable environment provides and enabling environment for production and the reverse is true.

4. Empirical Results

The results of the dynamic panel models are presented in Table 4. The results in the first two columns are for the models with HDI as the dependent variable, employing the two proxies for renewable energy (renewable electricity share of total electricity output or renewable electricity share of the total electricity consumed), which constitutes the key objective of the study. The last two have GDP per capita as their dependent variable.

The diagnostic tests of this model suggest that the four models validate the AR (2) tests, as designated by their p-values that are all above 0.05, hence not significant at a 5.0% level of significance and shows that the serial correlation of the error terms is not a second order serial correlation. The number of instruments for the four models is 36, which is less than the number of countries - 43. In addition, the Hansen over-identification test with insignificant p-values validates the instruments employed. Finally, the Pesaran CD test with insignificant p-values also confirms that there exists no cross-sectional independence that could bias the estimators. We, therefore, conclude that the estimators are robust and reliable enough for policy inferences.

The results show that renewable electricity share of total electricity output increases economic development annually by 0.000007, but the increase is significant only at 10%. This validates the growth hypothesis, though marginally. The very low coefficient and significance at the 10% level show that the proportion of renewable electricity to total electricity output is still insufficient and needs to be improved upon to achieve the desired impact on economic development. Incidentally, renewable electricity share of total electricity output also has a positive relationship with per capita GDP, but not significant even at a 10% level.

Meanwhile, the renewable electricity share of total electricity consumed contributes positively to economic development but not significantly. This validates the neutrality hypothesis. The probability value of 0.95 is greater than 0.1 and hence, not significant even at the 10% level. Interestingly, the renewable electricity share of the total electricity consumed has a significant and positive impact on the GDP per capita at a 1% significance level. Since GDP per capita is a component of GNI, which constitutes one of the indicators that make up HDI, it could be inferred that renewable electricity share of total electricity output/consumption has the

Table 4: Effect of Renewable Energy on Economic Development

Description	**HDI (1)**	**HDI (2)**	**GDP per capita (1)**	**GDP per capita (2)**
HDI (–1)	0.978***	0.982***		
	(0.00)	(0.00)		
GDP Per capita (–1)			1.02***	1.02***
			(0.00)	(0.00)
Renewable electricity share of total electricity output (%)	0.000007*		0.082	
	(0.09)		(0.18)	
Renewable electricity share of the total electricity consumed (%)		0.000001 (0.95)		1.05*** (0.00)
Government Effectiveness	0.00184**	0.00133**	0.75	7.81
	(0.04)	(0.02)	(0.9)	(0.46)
Private Sector Credit (% GDP)	0.00003	0.000024*	0.658***	0.339***
	(0.11)	(0.08)	(0.00)	(0.00)
Labour Force (%)	0.0000062	0.00016	0.449*	0.448*
	(0.7809)	(0.45)	(0.06)	(0.07)
Real Interest rate	–0.00005**	–0.00006***	−0.076	−0.197
	(0.02)	(0.00)	(0.59)	(0.102)
Exports (% GDP)	0.00008***	0.00008***	1.363***	1.73***
	(0.00)	(0.00)	(0.00)	(0.00)
Capital formation (% GDP)	0.000025*	0.00004***	−0.15	−0.11
	(0.09)	(0.00)	(0.44)	(0.64)
Political Stability	0.000032**	0.000025***		
	(0.02)	(0.00)		
constant	0.016***	0.0132***	–54.59***	–80.2***
	(0.00)	(0.00)	(0.00)	(0.00)
Test for AR(1) errors - z	–2.328**	–2.31**	–1.236	–1.27
	(0.02)	(0.021)	(0.22)	(0.204)
Test for AR(2) errors – z	–0.263	–0.226	–1.14	–1.14
	(0.79)	(0.82)	(0.25)	(0.25)
Hansen over-identification test	17.92	18.09	22.79	23.37
	(0.88)	(0.87)	(0.64)	(0.61)
Pesaran CD test for CSD	–1.104	–0.878	0.167	–0.36
	(0.27)	(0.38)	(0.87)	(0.72)
Number of Observations	188	188	188	188
Number of Instruments	36	36	35	35

Notes: Coefficients and standard errors (in brackets) are given in this table. And *** $p<0.01$, ** $p<0.05$, * $p<0.1$.

potential of significantly improving economic development in Africa if optimally utilised.

This argument is backed by an array of existing literature that established a positive and significant relationship between REC and economic growth in developed countries with relatively higher consumption of renewable energy [27,31,36,37]. Qudrat-Ullah & Nevo [21] employed the S-GMM for 37 African countries and found a positive relationship between renewable energy and economic growth at a 10% significant level.

Also, Chen et al [29] and Ahmed et al., [53] with a sample of 103 and 30 countries, respectively from both developed and developing countries came up with the same conclusion. However, for lower- and upper-middle-income countries in Africa, Adekoya et al. [24] employed the Augmented Mean Group technique and found that the effect of REC on economic growth is positive but insignificant.

Meanwhile, the one-period lag of HDI, government effectiveness, Exports (% GDP), Capital formation (% GDP) and Political Stability significantly and positively affect the HDI in the first two models. These results agree with a priori theoretical expectations. Increases in exports and capital formation (investment) translate to higher money in circulation; which through a multiplier effect will lead to an increase in production, higher employment, and ultimately an increase in economic development.

Government effectiveness and political stability speak to the need for Africa to have strong institutions as it significantly improves economic development. Government effectiveness in particular measures the quality of public service delivery, policy formulation, implementation, and the credibility of a government's commitment. While political stability measures the extent to which there are no political uprisings and the absence of violence/terrorism.

Private sector credit is also positively related to economic development in all four models, but not significant in the first, significant at 10% in the second model and significant at 1% in the third and fourth models. The real interest rate on the other hand shows a negative and significant relationship with HDI and per capita GDP in all four models as theoretically expected. Though considerably very small, a unit decreases in real interest rate increases HDI. This empirically supports the litany of literature that advocates for a reduction of real interest rates to boost local capital accumulation capacity and ultimately development in Africa.

5. Conclusion

In 2021, in a virtual summit, African residents shared different experiences of climate change from their country's perspectives, which translated to the humongous challenges or consequences of climate change [54]. (Despite the overwhelming and unpredictable nature of climate change consequences, African countries are faced with the reality of other challenges such as poverty, income inequality, poor infrastructure, and lower educational and health statutes amongst others. These competing challenges often cloud the importance of renewable energy development in most African countries. Given the increasing demand for energy in Africa as opposed to the low electricity generation capacity, this study, therefore, investigates if renewable energy share positively relates to economic development.

The findings show that renewable electricity's share of total electricity output has a marginally significant and positive contribution to economic development in Africa, while renewable electricity's share of the total electricity consumed has a positive but insignificant relationship with economic development. Inferences from the overall results posit that renewable electricity share of total electricity output/consumption has the potential to significantly improve economic development in Africa, and could if optimally utilized.

Specifically, the results show that in the context of increasing government effectiveness, exports, capital formation, and political stability while lowering interest rates, renewable electricity's share of total electricity output marginally improves economic development. This, therefore, means that the challenges of renewable energy development in Africa as earlier discussed (such as funding capacity, limited renewable energy technology development, the political will to implement, etc) need to be addressed to improve utilization and effectiveness.

It also implies that other determinants of economic development need to be addressed via the development and implementation of context-based policies. In this study, it is about improving government effectiveness in terms of improving public service delivery and credibility; improving exports via increase in production; and stimulating investments by lowering interest rates and creating an enabling environment.

Summarily, the results provide empirical evidence to support renewable electricity production and consumption as it does not only mitigate climate change, it also marginally contributes to the economic development of Africa.

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Appendix: Description of Variables

Description	**Source**	**Unit of Measurement**
HDI	UNDPHDR	Composite index (0-1)
GDP Percapita	WBI	GDP per capita (current US$)
Renewable electricity output	WBI	Electricity production from renewable sources, excluding hydroelectric (kWh)
Renewable electricity share of total electricity output	WBI	Renewable electricity output (% of total electricity output)
Renewable electricity share of total electricity consumed	WBI	Renewable energy consumption (% of total final energy consumption)
Exports (% GDP)	WBI	Exports of goods and services (% of GDP)
Private Sector Credit (% GDP)	WBI	Domestic credit to private sector (% of GDP)
Capital formation (% GDP)	WBI	Gross fixed capital formation (% of GDP)
Inflation (CPI)	WBI	Inflation, consumer prices (annual %)
Real Interest Rate	WBI	Real interest rate (%)
Government Effectiveness	LIAPI	Composite index
Political Stability	LIAPI	Composite index
Labour force participation	WBI	% of total population ages 15-64

Where WBI represents World Bank Indicators; LIAPI IS LOWY Institute Asia Power Index and UNDPHDR is UNDP Human Development Reports