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DECARBONIZATION MECHANISMS AND ECONOMIC GROWTH: EVIDENCE FROM SUB-SAHARAN AFRICA

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Abstract

This paper empirically analyses the effect of decarbonization mechanisms on economic growth in Sub-Saharan Africa. The study focuses on the effect of renewable energy consumption, decarbonization rate and green technology adoption as the principal decarbonization mechanisms, while the effect of population, industrialization and FDI are controlled for. The study employs secondary panel data collected from different countries in Sub-Saharan Africa between 2000 and 2024 representing 1,150 observations. The random-effects GLS model was chosen after diagnostic testing to account for the data. The results of the diagnostic tests showed that the data was stationary and free from autocorrelation, heteroscedasticity and multicollinearity. Furthermore, the data was adequately specified. The findings of the study *reveal that there is a positive and statistically significant effect of renewable energy consumption on economic growth. Additionally, a positive effect of the decarbonization rate and green technology adoption on economic growth was found. The model explained 79.11% of the variation in economic growth. The study concludes that decarbonization mechanisms have a positive effect on economic growth in Sub-Saharan Africa. Policy recommendations include increasing investment in renewable energy and green technologies to promote economic growth in the region.*

Keywords: Renewable energy consumption, decarbonization rate, green technology adoption, economic growth, Sub-Saharan Africa

INTRODUCTION

Climate change, energy insecurity and low levels of industrial productivity are the challenges that have been exacerbated by the development of Sub-Saharan Africa (Kinuthia & Wahome, 2026). Despite the region's low levels of emissions into the atmosphere, the area is exposed to the climate-related challenges of droughts, floods, energy poverty, food insecurity and the need for livelihoods that are sensitive to climate change (Ngwenya et al., 2018; Mikhaylov et al., 2020; Aktar et al., 2021; Maino & Emrullahu, 2022; Omotoso & Omotayo, 2024). In attempting to address these economic challenges, the region has turned to the study of how decarbonization can lead to both increased economic growth and increased levels of industrial productivity (Sarkodie & Adams, 2018; Asongu & Odhiambo, 2020; Wang & Feng, 2022; Ajibola et al., 2025).

Despite the region's abundance of natural resources, many Sub-Saharan African countries still lack access to sufficient energy resources for their growing economies. Furthermore, those resources are often from renewable energy sources. Studies have shown, however, that the introduction of renewable energy resources into the region can lead to positive impacts upon the environment and the economy of those countries (Acheampong et al., 2019; Nguyen & Kakinaka, 2019; Tamasiga et al., 2022; Bi et al., 2024; Mazorodze, 2025). Thus, it is predicted that the consumption of renewable energy within the Sub-Saharan African region will have a corresponding positive effect upon the region's economic growth and industrial productivity.

Relatedly, it is also important to investigate how fast the countries of the Sub-Saharan region are able to decarbonize their economies. Decarbonization can occur through the use of energy efficient technologies in the economy, shifting to decarbonized methods of power generation, decarbonizing industrial processes, and introducing methods of reducing deforestation and the use of less-efficient technologies within agriculture and manufacturing industries (Sahoo et al., 2022; Behera et al., 2023; Teklie, 2024; Balsalobre-Lorente et al., 2025; Lu et al., 2025). As with the discussion of renewable energy, however, these efforts to decarbonize can also be implemented in ways that cause economic difficulties for the countries of the region. Thus, research on the topic is necessary within the Sub-Saharan region of Africa.

Another important aspect of economic growth and decarbonization is the study of the adoption of green technologies within the region. The introduction and implementation of methods that lead to an increase in the efficiency of the economy or industries, or those that reduce the impact of those economies upon the environment will be essential to both economic and environmental sustainability (Romer, 1990; Porter & van der Linde, 1995). Studies of these technologies and their introduction into the Sub-Saharan region indicate that their use is associated with both economic and environmental benefits (Fernando et al., 2021; Tariq et al., 2022; Polemis & Tsionas, 2023; Han et al., 2025; Smaoui, 2025). Furthermore, these technologies can also allow the region to avoid the “carbon lock-in” effect, wherein the region is unable to change to alternative technologies due to the efficiency of the current methods of production.

The discussion of each of these factors is critically important for the Sub-Saharan region of Africa. Africa, as a continent, is still experiencing major transformations of its economies, industries, and demographics. The energy, technological and economic resources of the region will determine its ability to effectively utilize its growing population (Ayenew, 2022; Joo et al., 2022; Ofori et al., 2022; Anchi et al., 2023; Djeunankan et al., 2024). Thus, it is essential to determine an appropriate method of economic development for the region that accounts for its need to decarbonize its economy.

Relatedly, many current studies have provided evidence for the effects of each of these discussed variables upon economic growth within the Sub-Saharan region. For instance, studies of renewable energy have indicated that the use of renewable energy sources has led to improvements in economic growth (Diallo, 2024; Mazorodze, 2025; Yaï et al., 2025). Other studies, however, show that the impact of renewable energy upon economic growth is dependent upon various other factors, such as the level of development of the country, its infrastructure, its industries, and its available funds for economic development (Khan et al., 2020; Prempeh et al., 2024; Wang et al., 2025). Relatedly, other studies on decarbonization have indicated both that decarbonization can impact economic productivity positively (Farzanegan & Markwardt, 2018), as well as that the transition to decarbonization efforts can negatively impact economic outputs during the initial period of implementation of those changes (Nathaniel & Iheonu, 2019; Baloch & Danish, 2022; Rasheed et al., 2024). Finally, studies of green technology adoption have indicated that while such technology can impact the economy positively, such changes only occur within countries that have the technological and economic capability of adopting these technologies (Arner et al., 2020; Tsindeliani et al., 2022; Feng et al., 2024; Manu, 2025).

There are several justifications for the performance of the study that will be published with this research paper. First, most existing studies related to decarbonization use carbon emissions as their main measure of success of implementation of decarbonization processes. Fewer studies, however, have examined whether these same decarbonization processes can contribute to economic growth within the Sub-Saharan region of Africa. Second, most studies related to renewable energy, decarbonization rate, and green technology adoption have been performed separately of one another. Finally, the unique characteristics of the Sub-Saharan region may require different effects from decarbonization processes than those exhibited by other regions of the world. Thus, each of these topics will be studied in detail in the current study to determine their potential effects upon the economic growth of Sub-Saharan Africa.

Accordingly, the main objectives of this study will be to determine the effect of renewable energy consumption upon economic growth within Sub-Saharan Africa, to determine the effect of the decarbonization rate upon economic growth within Sub-Saharan Africa, and to determine the impact of the adoption of green technologies upon economic growth within the region.

The remainder of this paper is organized as follows. Section 2 presents a review of the relevant literature related to each of these topics. Section 3 presents the data that will be used to support these literature reviews, as well as the ways in which the variables related to these topics will be measured. Section 4 presents the tests that will be applied to these data and variables, as well as the results of those analyses. Section 5 presents the conclusions that can be drawn from these analyses, recommendations based upon those conclusions, limitations to the research that has been performed, and suggestions regarding future research on these topics.

LITERATURE REVIEW AND HYPOTHESES DEVELOPMENT

Theoretical review

The study rests on four economic theories: the neoclassical growth model, endogenous growth theory, the environmental Kuznets curve and the Porter hypothesis. The neoclassical growth model argues that economic growth arises out of investments in capital, labour and technological progress (Solow, 1956). Within this model, the introduction of renewable energy, decarbonization and green technology can be considered a means of increasing productivity. Variables such as population, industrialization and FDI can be controlled for as they are factors considered to be associated with economic growth according to the neoclassical model (Mankiw et al., 1992).

Endogenous growth theory suggests that technological developments, innovations and the gains in knowledge are factors that contribute to economic growth (Romer, 1990). The introduction of green technology into the economy is inherently related to these concepts as the technology can increase productivity and efficiency. Thus, green technology has implications for both the environment and economic growth.

The environmental Kuznets curve suggests that environmental impact increases with economic growth up to a certain point after which the increase in power of a nation to control its environment results in a decline in that impact (Grossman & Krueger, 1995). While the African region is increasing its economic activity, it seeks to do so without significantly impacting the environment. Decarbonization of the economy may, therefore, accelerate the environmental benefits of economic growth before the region reaches the high levels of economic activity that would otherwise lead to environmental destruction.

The Porter hypothesis suggests that environmental regulations and a focus on decarbonization lead to innovations in processes and technologies within industries to increase their competitiveness (Porter & van der Linde, 1995). This hypothesis can help to explain why the incorporation of renewable energy, decarbonization and green technology may have a positive impact on the economy. These processes have the potential to increase the competitiveness of industries and result in economic growth.

Renewable energy consumption and economic growth

Renewable energy consumption has become a vital component of the sustainable growth of the economy of different countries in the world. The theoretical justification for the use of renewable energy for economic growth is founded on the premise that the use of such energy will improve energy security, reduce the volatility of fuel prices, and increase the rate of growth of the economies through the reduction of production costs and the improvement in the rate of electricity access (Acheampong et al., 2021; Diallo, 2024; Mazorodze, 2025). The use of renewable energy has significant implications for Sub-Saharan African economies as the region continues to experience deficits in the grid and fuel imports that power their economies.

Acheampong et al. (2021) researched the impact of the use of renewable energy on the environment and the growth of the economy of Sub-Saharan African countries. Diallo (2024) investigated 25 countries in the region and established that the use of renewable energy has implications for the economic growth of the region. Furthermore, Mazorodze (2025) investigated the use of renewable energy and its impact on the growth of the green economy of 22 countries in Sub-Saharan Africa. The results established that the use of renewable energy could become a means of increasing the growth of the green economy in the region.

Other studies that investigated the impact of the use of renewable energy on economic growth outside of Sub-Saharan Africa included the research of Khan et al. (2020) on 20 countries across the world. The study established that the impact of the use of renewable energy on the environment and the growth of the economy varied significantly from country to country within the different economic and development conditions. Gyamfi et al. (2021) studied the effects of using hydroelectric and renewable energy in the growth of emerging economies. The results of the study indicated that there was a relationship between the two variables. In a similar study, Koengkan et al. (2020) discovered that the use of renewable energy could significantly reduce the effects of pollution on the economy. Bi et al. (2024) studied the impact of adopting renewable energy on developed and developing economies and found that the outcomes for the two categories of economies were significantly different from one another.

The use of renewable energy could also impact the economy of Sub-Saharan African countries through the use of decentralised electricity. The implementation of solar mini-grids and other technology that increases the use of renewable energy in electricity generation could have a significant impact on the growth of the region's economies (Tamasiga et al., 2022; He et al., 2024; Town Carabajal et al., 2024). Such technologies have the potential to improve the income of individuals in the region, increase safety, increase the productivity of economies, and improve gender-related opportunities for the people in the region. However, the integration of renewable energy projects into the region's industrial and agricultural economies will have a more significant and lasting impact on their economic growth.

Based on the research that has been conducted on the subject of renewable energy use and economic growth in Sub-Saharan Africa, the following hypothesis will be tested:
H1. There is a significant positive effect of renewable energy consumption on the economic growth of Sub-Saharan Africa.

Decarbonization rate and economic growth

Decarbonization rate refers to the progress that a country makes toward producing and consuming less carbon. This can be accomplished through a variety of means, including reducing carbon emissions per capita, using more clean energy sources, and increasing the energy efficiency of the nation's industries and technologies. While the growth effect of decarbonization can be positive due to increased energy efficiency, it can also be negative if the technologies used during the decarbonization process are not yet productive enough to create significant reductions in carbon emissions (Sahoo et al., 2022; Behera et al., 2023; Balsalobre-Lorente et al., 2025).

The decarbonization of the economies of the world is considered to be an opportunity for the world's economies rather than a cost that they must bear. Authors Behera et al. (2023) argued that using renewable energy and incorporating green technologies into economic processes are essential to achieving carbon neutrality in the world's emerging economies. Sahoo et al. (2022) also argued that technological innovation, economic structure, and population density are factors that impact ecological pressure on the Earth, indicating their impact upon the decarbonization of the planet's economies. Furthermore, authors Lu et al. (2025) conducted study after finding that the use of renewable energy resources is linked to green growth in the economies, indicating the relationship between economic and environmental goals for these nations.

African nations that are experiencing rapid industrialization can benefit from the decarbonisation of their economies. While industrialization often comes with an increase in the energy demands of those industries, the use of low-carbon methods to industrialize can reduce the environmental costs of those industries. Authors Djeunankan et al. (2024) studied energy poverty and industrialization in African nations and found that energy poverty negatively impacts industrialization. Authors Chen et al. (2025) also examined the link between industrialization, oil prices, and carbon dioxide emissions from African nations. Their study indicated that the use of renewable energy could reduce the emissions created by these rapidly industrializing nations. Rasheed et al. (2024) also discovered that artificial intelligence, the use of renewable energy, and the growth of industrial performances are all factors that impact the environmental sustainability of African nations.

There are various ways in which decarbonization can have a positive effect upon the economic growth of a region. The use of energy-efficient technologies can lower the costs of energy use for the economy. Additionally, businesses that use low-carbon processes will be able to compete better with other industries that may emit more carbon into the environment. The use of low-carbon methods in the production of goods can also increase the productivity of the labor force, as well as lower the costs that the economy must undertake to control pollution. Finally, the economic growth that is created through the decarbonization of economic processes can stimulate the development of new technologies within the economy (Aktar et al., 2021; Subhani et al., 2021; Wang & Feng, 2022; Marinov, 2024). Each of these benefits indicates the potential for the decarbonization rate to have a positive influence upon economic growth within Sub-Saharan Africa.

There are, however, some counter-arguments regarding the positive effect of decarbonization upon economic growth. For instance, if the industries that are decarbonizing are also contracting in size, then the decarbonization of those economies will have a negative effect upon economic growth. Furthermore, if the technologies that are implemented as part of the decarbonization processes are expensive to initially implement into those economies, that could have a negative effect upon economic growth. For these and similar reasons, evidence based upon panel data needs to be gathered and analyzed.

Based on these various findings in the literature regarding decarbonization and economic growth, the following hypothesis can be made:

H2. Decarbonization rate has a significant positive effect on economic growth in Sub-Saharan Africa.

Green technology adoption and economic growth

Green technology adoption relates to the use of technologies that are safer for the environment, use renewable energy, reduce emissions, and increase efficiency. Technology is often identified in endogenous growth theory as a source of productivity growth. Furthermore, the Porter hypothesis states that using processes and technologies that are better for the environment will boost innovation within an economy. Empirical studies have found support for the adoption of green technologies will increase green growth, renewable energy, and the environment's performance (Tariq et al., 2022; Teklie, 2024; Han et al., 2025; Smaoui, 2025).

Teklie investigated green innovation, renewable energy, and green growth in African countries. His findings indicated that green innovation is relevant to the growth that is needed to ensure the sustainability of African economies. Han et al. investigated the impact of technological innovation on the adoption of renewable energy and the sustainability of the environment. The results of the study revealed that technological innovation had a positive effect on the adoption of renewable energy and the sustainability of the environment. Smaoui investigated the relationship between renewable energy, environmental technology innovation, and green economic growth in South Africa. Results indicated that there was a significant effect between these three variables. Manu investigated the effect of green innovation on the environment and digital technologies. Findings indicated that digital technologies have a significant effect on the environment and green innovation in the African continent.

Digital finance and green technology are connected in various studies. Arner et al. studied FinTech and its influence on sustainable finance. Results of the study indicated that FinTech has the potential to influence sustainable finance. Bhatnagar and Sharma investigated green finance. Findings of the study indicated that green finance had a significant impact on the sustainability of investments. Tsindeliani et al. studied the digital transformation of banking institutions and its impact on sustainable development. The results of the study indicated that there is a relationship between the digital transformation of banking institutions and sustainable development. Furthermore, Feng et al. investigated digital finance and its effect on carbon emissions. Findings of the study indicated that digital financial development has an impact on carbon emissions. These findings are essential to understand the implications of adopting green technology in Sub-Saharan Africa.

The environmental technology literature also cautions about the proper direction of technology. For instance, Polemis and Tsionas studied blockchain technology and its impact on the environment. Findings of the study indicated that blockchain technology can have negative consequences for the environment. Furthermore, Liu et al. studied the impact of digital finance on the environment. Results of the study indicated that digital finance impacts the consumption of energy and the emissions of carbon dioxide into the atmosphere. Furthermore, Firdousi et al. studied the same topic as Liu et al. Findings of Firdousi et al. are similar to those of Liu et al., indicating that digital finance can impact sustainability of the environment. Therefore, the adoption of green technology in the Sub-Saharan African region should be measured in relation to clean energy and the reduction of carbon emissions.

The adoption of green technology can have a positive impact on the Sub-Saharan African economy. Various forms of green technology, such as solar and wind power, clean cooking stoves, efficient irrigation methods, green transport technologies, smart metering technologies, and green manufacturing processes can be adopted to boost the region's economic growth (Ofori et al., 2022; Prempeh et al., 2024; Antwi et al., 2024; Okwu et al., 2025). Additionally, the region can experience an increase in green foreign direct investment as a result of the adoption of green technologies.

Based on the studies reviewed in this paper, the following hypothesis is proposed:

H3. Green technology adoption has a significant positive effect on economic growth in Sub-Saharan Africa.

RESEARCH METHODOLOGY

Sample size and data

The study utilized panel data from 46 Sub-Saharan African countries for the period 2000–2024, yielding 1,150 observations. The period was selected because it provides a sufficiently long time series to capture changes in renewable energy, carbon emissions, climate conditions, economic growth and financial development, while also reflecting major developments in green technology and decarbonization. The year 2000 was chosen due to improved availability and comparability of cross-country data, while 2024 represented the most recent year with sufficiently complete data at the time of the study. Data were obtained from secondary sources, including the World Bank DataBank and other relevant databases on green technology and decarbonization.

Economic growth was chosen as the dependent variable for the analysis. The independent variables included renewable energy consumption, decarbonization rate, and the adoption of green technology. Additionally, population, industrialization, and foreign direct investment were controlled for as they are variables that are often associated with economic growth. Finally, the panel data model was chosen for the study due to the ability of the model to account for both within and between variation over time while maintaining control over other variables.

Measurement of variables

This section presents the measurement of the dependent, independent and control variables. The measurements are summarized in Table 1.

Table 1: Measurement of variables

Variable category	Variable	Acronym	Measurement	Expected sign	Source
Dependent variable	Economic growth	EG	Gross domestic product, measured using GDP in current US dollars or a standardized GDP indicator.	Positive	World Bank DataBank
Independent variable	Renewable energy consumption	REC	Renewable energy consumption measured in kilowatt-hours or equivalent renewable energy consumption indicator.	Positive	World Bank DataBank
Independent variable	Decarbonization rate	DR	Carbon dioxide emissions per capita or carbon-intensity-based indicator capturing decarbonization progress.	Positive	Climate and carbon datasets

Table 1…

Independent variable	Green technology adoption	GTA	Clean technology investment indicator expressed as 1 when green technology adoption was recorded in a country-year and 0 otherwise.	Positive	World Bank and energy datasets
Control variable	Population	POP	Number of people usually living in the country.	Positive	World Bank DataBank
Control variable	Industrialization	IND	Manufacturing value added or industrial share of GDP.	Positive	World Bank DataBank
Control variable	Foreign direct investment	FDI	Net FDI inflows expressed as a share of GDP.	Positive	World Bank DataBank

Model specification

The study utilized panel regression analysis to determine the effect of renewable energy consumption, decarbonization rate, and green technology adoption on economic growth. The model was developed in two stages. The first stage modeled the effect of the control variables alone. The second stage included the decarbonization mechanisms to determine the effect of these variables while controlling for the effect of the control variables.

$$EG_{it} = \beta_0 + \beta_1 POP_{1it} + \beta_2 IND_{2it} + \beta_3 FDI_{3it} + \varepsilon_{it} \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots .1$$

$$EG_{it} = \beta_0 + \beta_1 POP_{it} + \beta_2 IND_{it} + \beta_3 FDI_{it} + \beta_4 REN_{it} + \beta_5 DR_{it} + \beta_6 GTA_{it} + \varepsilon_{it} \dots\dots\dots\dots\dots\dots\dots\dots\dots 2$$

Where,

EG denotes economic growth, POP denotes population, IND denotes industrialization, FDI denotes foreign direct investment, REC denotes renewable energy consumption, DR denotes decarbonization rate, GTA denotes green technology adoption, β0 is the constant, β1-β6 are estimated coefficients, i represents country, t represents year and ε is the error term. The random-effects GLS regression was used for interpretation of the models as the results of the Hausman test supported the random-effects model.

EMPIRICAL FINDINGS AND DISCUSSION

Diagnostic tests

A number of diagnostic tests were conducted prior to hypothesis testing to confirm the suitability of the panel regression model. The Harris-Tzavalis panel unit root test indicated that all of the variables were stationary due to the p-values all being below the 0.05 level of significance. These results indicate that there were no unit roots within the variables, and that the regression model was not likely to have produced spurious results. The Wooldridge test for autocorrelation yielded an F value of 3.055 with a p-value of 0.0933. As the p-value is statistically higher than the 0.05 level of significance, the null hypothesis of no first-order autocorrelation is not rejected. The Breusch-Pagan/Cook-Weisberg test for heteroscedasticity indicated a chi-squared test statistic of 0.32 with a p-value of 0.5726. This p-value indicates that there is no statistically significant heteroscedasticity within the model. Additionally, the variance inflation factors (VIFs) for each of the variables ranged from 1.05 to 1.30, and the mean VIF (excluding the variable for institutional quality) was 1.11, indicating that multicollinearity was not an issue within the model. The Ramsey RESET test for model specification yielded an F test statistic of 0.62 with a p-value of .5997, indicating that the model is adequately specified. Finally, the Hausman test for endogeneity and model selection returned a chi-squared test statistic of 4.79 with a p-value of .5710, indicating support for the random-effects model over the fixed-effects model. Thus, these tests indicate the reliability of the regression model (Gujarati & Porter, 2009; Wooldridge, 2010).

Table 2: Diagnostic tests

Diagnostic area	Test applied	Key statistic/result	Decision
Stationarity	Harris-Tzavalis panel unit root test	All p-values = .0000	Variables stationary
Autocorrelation	Wooldridge test	$F(1,24) = 3.055$, $p = .0933$	No first-order autocorrelation
Heteroscedasticity	Breusch-Pagan/ Cook-Weisberg	$\chi 2 = 0.32$, $p = .5726$	No heteroscedasticity
Multicollinearity	VIF	VIF range = 1.05-1.30; mean VIF = 1.11	No serious multicollinearity
Model specification	Ramsey RESET	$F(3,1143) = 0.62$, $p = .5997$	Model adequately specified
Model selection	Hausman test	$\chi 2(6) = 4.79$, $p = .5710$	Random effects selected

Descriptive statistics

Table 3 presents the descriptive statistics for economic growth, population, industrialization, foreign direct investment, renewable energy consumption, decarbonization rate and green technology adoption. Economic growth experienced a mean of 3.18e+10 with a standard deviation of 7.54e+10, indicating that there are both small and large economies in the region. This level of economic growth is to be expected within the region given the differences in the population, resources, industry, and energy systems existing within each of the Sub-Saharan African countries. The population within the region exhibited means of 1.92e+07 with a standard deviation of 3.04e+07, indicating a variation in the populations of the individual countries within the region. The population impacts the economic growth of a nation due to their ability to contribute to the economy (Adeleye et al., 2020; Joo et al., 2022).

Industrialization within the region exhibited means of 10.264 with a standard deviation of 5.954. Industrialization is one of the major economic growth contributors within the region due to its ability to generate more value within the economy, employ individuals within the region, and contribute to the learning of new technologies (Anchi et al., 2023; Djeunankan et al., 2024). Foreign direct investment within the region exhibited means of 5.713 with a standard deviation of 14.292, with values ranging from -47.985 to 100. Foreign direct investment can impact economic growth within the region, though studies demonstrate the impacts can be varying in nature (Asafo-Agyei & Kodongo, 2022; Awad, 2021; Kinuthia, Onyango & Adaramola, 2025; Wako, 2021).

The renewable energy consumption values within the region exhibited means of 2.88e+08 with a standard deviation of 1.31e+09, indicating the differences in the renewable energy consumption within each of the countries within the region. Some countries within the region have more renewable energy sources than others. Furthermore, decarbonization rate exhibited means of 1.001 with a standard deviation of 1.960, indicating that some countries within the region did not experience decarbonization within their economies and others did experience decarbonization. Lastly, green technology adoption exhibited a mean of 0.116 with a standard deviation of 0.320, indicating that the use of green technologies is still limited within the majority of the countries within the region. Furthermore, studies confirm these findings regarding the lack of development of green technologies within the African continent (Kinuthia et al., 2025; Prempeh et al 2024; Teklie, 2024; Bhatnagar & Sharma, 2022).

Table 3: Descriptive Statistics

Variable	Obs.	Mean	Std. dev.	Minimum	Maximum
Economic growth (EG)	1,150	3.18e+10	7.54e+10	1.60e+08	5.41e+11
Population (POP)	1,150	1.92e+07	3.04e+07	82,894.03	2.33e+08
Industrialization (IND)	1,150	10.264	5.954	0.000	38.248
Foreign direct investment (FDI)	1,150	5.713	14.292	-47.985	100.000
Renewable energy consumption (REC)	1,150	2.88e+08	1.31e+09	-3.08e+09	1.49e+10
Decarbonization rate (DR)	1,150	1.001	1.960	0.000	12.028
Green technology adoption (GTA)	1,150	0.116	0.320	0.000	1.000

Correlation analysis

Correlation analysis was performed to determine the direction and strength of bivariate relationships among study variables. Economic growth was found to have a strong and positive correlation with population ($r = .8257$, $p < .05$). This means that countries with higher population bases also tended to show higher aggregate economic output. Renewable energy consumption was also positively and significantly correlated with economic growth ($r = .3557$, $p < .05$), meaning that countries that consumed higher levels of renewable energy also showed higher economic growth. This finding supports the argument that energy security from renewable energy consumption can support clean forms of production (Acheampong et al., 2021; Diallo, 2024; Mazorodze, 2025). Decarbonization rate was found to be positively and significantly correlated with economic growth ($r = .2709$, $p < .05$). In other words, countries that were making progress toward a lower-carbon economy also tended to show stronger economic growth outcomes. Green technology adoption was similarly found to be positively and significantly correlated with economic growth ($r = .1967$, $p < .05$) implying that investments in clean technologies and green projects are associated with positive economic outcomes. The correlation results suggest some initial evidence that decarbonization mechanisms may be associated with growth. Regression analysis is needed to determine whether these correlations hold true after controlling for confounding variables such as population, industrialization and foreign direct investment.

Table 4: Correlation Results

Variable	EG	POP	IND	FDI	REC	DR	GTA
EG	1.000						
POP	.8257*	1.000					
IND	-.0444	-.1367*	1.000				
FDI	-.1068*	-.1202*	-.0908*	1.000			
REC	.3557*	.2785*	-.0888*	-.0378	1.000		
DR	.2709*	-.0486	.1421*	.1189*	.0989*	1.000	
GTA	.1967*	.1826*	.0492	-.0396	.1155*	.0292	1.000

Note. * $p < .05$

Regression results

A random-effects GLS regression model was used to test the direct effects of renewable energy consumption, decarbonization rate and green technology adoption on economic growth, while statistically controlling for the effects of population, industrialization and FDI. The model had strong explanatory power, with a within R^2 of .7904, a between R^2 of .9776 and an overall R^2 value of .7911. Thus, around 79.11% of the variation in economic growth in Sub-Saharan African countries is explained by the variables included in the model. Furthermore, the Wald chi-square test was found to be statistically significant, indicating that the explanatory variables have a statistically significant effect on economic growth (Wald $\chi2(10) = 4328.38$, $p < .001$).

Population had a statistically significant and positive effect on economic growth ($B = .8071$, $p < .001$). Industrialization had a positive coefficient ($B = .0273$) and was marginally significant at the 10% level of statistical significance ($p = .051$). Finally, FDI had a negative coefficient and was statistically significant ($B = -.0381$, $p = .006$), indicating that FDI was associated with lower economic growth rates in Sub-Saharan African countries (Wako, 2021; Asafo-Agyei & Kodongo, 2022; Okwu et al., 2025).

Renewable energy consumption had a positive and statistically significant effect upon economic growth ($B = .0992$, $z = 6.96$, $p < .001$, 95% CI [.0713, .1272]). Thus, the first hypothesis was supported by the data. The use of renewable energy was associated with higher rates of economic growth. Furthermore, this finding agrees with studies that found that renewable energy and green economic development promotes both economic and green growth in African and developing world countries (Acheampong et al., 2021; Diallo, 2024; Mazorodze, 2025; Lu et al., 2025).

Decarbonization rate also had a positive and statistically significant effect upon economic growth (B = .3002, z = 21.60, $p < .001$, 95% CI [.2730, .3275]). Thus, the second hypothesis was supported by the results. The decarbonization of Sub-Saharan African economies was associated with higher economic growth rates. The reasons for this relationship may be due to the link between decarbonization and increased energy efficiency and increased development of green technologies (Behera et al., 2023; Rasheed et al., 2024; Balsalobre-Lorente et al., 2025).

Finally, green technology adoption had a positive effect upon economic growth (B = .1967, z = 6.80, $p < .001$, 95% CI [.1400, .2534]). Thus, the third hypothesis was supported by the study results. Countries that adopted green and environmentally-friendly technologies within their economies experienced higher rates of economic growth than those countries without the adoption of such technologies. Furthermore, these findings agree with other studies that have found that the adoption of green technologies and the development of clean technologies is associated with both green growth and sustainable development of the economies in which they are implemented (Teklie, 2024; Han et al., 2025; Smaoui, 2025; Manu, 2025).

Overall, then, the results of the regression model indicate that each of the mechanisms of decarbonization are associated with economic growth in Sub-Saharan African countries. Furthermore, the individual results indicate that the increase in the consumption of renewable energy, the decarbonization of the countries' economies and the adoption of green technology are all associated with economic growth. Thus, the findings of the study indicate that the African countries do not have to choose between pursuing economic growth and decarbonization of their economies. Instead, each of these outcomes can be pursued simultaneously. In other words, the growth of the economies of Sub-Saharan African countries and their decarbonization can occur concurrently.

Table 5: Regression results

Variable	Coef.	Std. Err.	z	p	95% CI
Population	.8071	.0145	55.65	.000	[.7786, .8355]
Industrialization	.0273	.0140	1.96	.051	[-.0001, .0547]
Foreign direct investment	-.0381	.0138	-2.76	.006	[-.0652, -.0110]
Renewable energy consumption	.0992	.0142	6.96	.000	[.0713, .1272]

Decarbonization rate	.3002	.0139	21.60	.000	[.2730, .3275]
Green technology adoption	.1967	.0289	6.80	.000	[.1400, .2534]
Constant	-1.24e-09	.0135	0.00	1.000	[-.0265, .0265]

Table 5…

Model summary: Number of observations = 1,150; number of groups = 25;
within R^2 = .7904; between R^2 = .9776; overall R^2 = .7911;
Wald $\chi^2(10)$ = 4328.38; $p < .001$; sigma_u = 0; sigma_e = .4619; rho = 0

Discussion of findings

The positive effect of renewable energy consumption shows that the energy transition can accommodate the economic growth needs of the Sub-Saharan Africa region. The use of renewable energy sources will significantly reduce the long-term dependence on imported fossil fuels. These energy sources provide increased reliability for electricity production and will reduce the disruptions to economic activities (Yaï et al., 2025; He et al., 2024; Prempeh et al., 2024).

The positive coefficient for the decarbonization rate suggests that the countries that decarbonize the fastest will improve their productive efficiency within the economy. Decarbonization requires the use of modern technology to improve the efficiency of energy use in sectors like transport, industry, and agriculture. As global trade relies on these factors, the use of decarbonization technology will give African countries a more competitive advantage in international markets (Bhatnagar & Sharma, 2022; Antwi et al., 2024; Balsalobre-Lorente et al., 2025).

The positive coefficient for the adoption of green technology indicates that the use of energy-efficient green technology will boost the region's economic activities. Many Sub-Saharan African countries have abundant renewable energy resources but lack the technology to convert these resources into electricity. The adoption of green technology will significantly improve the region's economic potential (Arner et al., 2020; Tchamyou et al., 2019; Teklie, 2024; Han et al., 2025).

The negative coefficient for FDI in the full model is also a helpful result. As expected, FDI will have a negative effect on the region's economic activities. This result could be due to FDI in high-emission sectors rather than sectors focused on economic and energy decarbonization. However, green FDI in the region's renewable energy sectors will have the most significant positive effects on economic growth (Awad, 2021; Wako, 2021; Asafo-Agyei & Kodongo, 2022; Ofori et al., 2022).

Overall, these results all contribute to a perspective on the region's structural transformation toward green economic activities. The various positive coefficients suggest that the region can experience strong economic growth while decarbonizing its energy economy. Such economic growth will occur without locking the region into high-carbon economic activities. These results are in line with other studies on the potential of the Sub-Saharan Africa region to undertake a structural transformation toward green economic activities (Marinov, 2024; Wang et al., 2025; Lu et al., 2025; Smaoui, 2025).

CONCLUSIONS AND RECOMMENDATIONS

This study investigates the impact of decarbonization on the economic growth of Sub-Saharan African countries. The study considers three variables that may influence decarbonization: the consumption of renewable energy, the decarbonization rate, and the adoption of green technologies. The variables that are controlled for in the model are the population, industrialization, and FDI. A total of 1,150 observations from the period 2000-2024 were used in the model to determine the relationship between the different variables. The results of the model, which accounted for 79.11% of the economic growth in the region, demonstrate that each of the three variables has a positive influence on the economic growth of Sub-Saharan African countries.

The results indicate that the consumption of renewable energy in Sub-Saharan African countries has a positive and statistically significant influence on the economic growth of the region. This factor indicates that renewable energy is not just used to decarbonate the region but also acts as a source of economic growth for the region. The increased use of renewable energy creates various opportunities for economic activity.

The decarbonization rate within Sub-Saharan African countries also has a positive and statistically significant relationship with the economic growth of the region. Among the three decarbonization variables, this has the strongest relationship with economic growth. The decarbonization rate is linked to the economic growth of the region due to the increased efficiency of economic activities as they become decarbonized.

The adoption of green technologies within the region has also been proven to have a positive and statistically significant relationship with the economic growth of Sub-Saharan Africa. The introduction and adoption of green technologies allow the region to produce goods and services in a way that is economically and environmentally sustainable.

The policy implications of these findings suggest that the government of Sub-Saharan African countries should increase their investments in the production of renewable energy. Their renewable energy policies should be linked to the industrialization of the region. Furthermore, they should improve their grids and laws regarding the regulation of mini-grids to increase the growth of renewable energy use in the region.

The governments of Sub-Saharan African countries should also incorporate the decarbonization of their economies into their economic growth strategies. Many of their economic strategies should incorporate decarbonization elements such as energy efficiency and the use of sustainable infrastructure.

The countries in the Sub-Saharan African region should also work to increase the adoption of green technologies. Their governments can accomplish this by establishing financing programs for green technologies, forming public-private partnerships, and implementing governmental incentives for industries that adopt these technologies. Green technologies should be adopted by industries such as agriculture, transport, construction, and manufacturing.

Finally, their FDI policies should be redesigned to encourage countries to invest in the region in the development of green technologies and processes. Even though the coefficient for FDI in the model is significantly negative, targeted incentives for FDI will encourage these countries to contribute to the economic growth of the region.

The limitations of this study include the fact that all data was secondary data. Furthermore, the adoption of green technology was represented by a dummy variable. The study also utilized aggregate data for each country, which discards possible differences within the countries. Future studies could utilize sectoral data for these countries, case studies of individual countries, and use other representations of the adoption of green technologies.

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