

Research Article

Clean Energy and Financial Development as Determinants of Sustainable Development in sub-Saharan Africa

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Abstract

Sub-Saharan Africa is prominently involved in a range of established policies and international initiatives aimed at advancing clean energy and financial development, which are pivotal for addressing environmental concerns, stimulating economic growth, and promoting sustainable investment. However, access to clean energy, insufficient political commitment, and a lack of clear policy guidance remain major issues. This study investigated the relationship between clean energy access, financial development, and sustainable development in sub-Saharan Africa, aiming to address critical research gaps. Financial Development exhibited a positive and significant relationship with gross domestic product per capita via analysis using panel data and employing panel Fully Modified Least Squares (FMOLS) regression, after determining that all the variables are stationary at $I(1)$ except one, which is stationary at $I(0)$. This suggests that a well-developed financial sector positively impacts economic growth by facilitating access to capital. Also, Renewable Energy Consumption demonstrated a negative association with gross domestic product per capita, possibly due to initial investment costs and technological constraints. The interaction effect between financial development and renewable energy also showed a negative impact on gross domestic product per capita, indicating a mitigating influence when both factors are considered together. Additionally, Trade Openness and Foreign Direct Investment exhibited notable impacts on gross domestic product per capita, with higher levels of trade openness and foreign direct investment potentially leading to lower economic growth. Based on the findings, the policy recommendations of this study are to strengthen the financial sector with efficient credit allocation, promote clean energy adoption despite challenges, mitigate trade openness impacts through diversification, and evaluate FDI for sustainable development alignment that enhances local benefits.

Keywords: financial development; renewable energy; foreign direct investment; gross domestic product

1. Introduction

Sustainable development strives to meet present needs without jeopardising future generations. It seeks a harmonious balance among social, economic and environmental factors, ensuring a better future for all, while preserving the planet's integrity. Sustainable development involves balancing economic, social and environmental dimensions (Grant, 2010; Ozili, 2022; Ruggerio, 2021). Sustainable development has historically been derived from economics as a discipline. Conceptually, the term "Sustainable Development" is composed of two distinct words: "sustainable" and "development." Each term has been defined from numerous viewpoints, which has led to the examination of sustainable development from various perspectives, resulting in a diverse range of definitions (Halkos and Gkampoura, 2021; Sheehy and Farneti, 2021). Sustainable development is a paradigm and concept that advocates the enhancement of living standards while ensuring the protection of the Earth's ecosystems and mitigating environmental threats, such as deforestation and water and air pollution, which can lead to significant challenges, such as climate change and species extinction (Benaim and Raftis, 2008; Jennings et al. 2019; Wang et al. 2024). From this perspective, sustainable development seeks to balance social progress, environmental stability, and economic growth (Zhai and Chang, 2019).

Despite progress, sustainable development in sub-Saharan Africa faces several challenges. The key obstacles identified include unrealistic goal setting, insufficient political commitment, inadequate participation, lack of clear policy guidance, absence of synergy, limited capacity, an imbalanced focus on a single development pillar, and rapid population growth (Otim et al. 2020; Schut and Giller, 2020). This underscores the argument that intergenerational equity is inherent in the concept of sustainable development, which acknowledges both the short- and long-term implications of sustainability and sustainable development (Stoddart, 2019). It is imperative to prioritise sustainability issues in the formulation of long-term development strategies (O'Neill et al. 2018; Sachs et al. 2019; Yang et al. 2020). Climate change and global warming are pivotal in shaping Sustainable Development Goals in sub-Saharan African countries. To transcend the rhetoric of sustainable development and pursue a substantive agenda, a precise definition of this concept and a comprehensive understanding of its core dimensions are essential. Low-carbon economies have gained popularity as a research topic. There is a negative correlation between climate change and economic livelihoods, as well as the environment. Consequently, there is a need for clean energy. Clean energy does not produce carbon dioxide (CO₂) emissions during operation, and utilising this will help combat global warming and reduce the risks of droughts, wildfires and flooding associated with climate change. Clean energy plays a vital role in combating climate change, reducing pollution, and achieving sustainable development goals.

The United Nations Environment Program (UNEP) states that US\$2.6 trillion was invested in renewable energy (mainly hydropower) between 2010 and 2019. Additionally, the study discovered that global investments in renewable energy capacity in 2018 totalled US\$272.9 billion, which is three times the amount allocated to gas-fired and coal-fired generation. Furthermore, a 10% increase occurred in the amount allotted for the research and development of renewable energy. The amount of money invested in renewable energy has also increased over time. Over the past ten years, there has been a notable increase in the use of renewable energy (World Bank, 2020). For instance, the share of renewable energy in the world's total energy consumption rose from 17.04% to 18.05% between 2005 and 2015 (World Bank, 2020). According to the IEA (2020), the first quarter of 2020 saw an increase of 1.5% in the global consumption of renewable energy across all sectors compared to the same period in 2019. Nonetheless, there remains a substantial global disparity between countries in access to renewable energy.

Africa, especially sub-Saharan Africa (SSA), has the lowest rates of clean energy accessibility, whereas America and Europe have the highest levels. This calls into doubt the sub-region's ability to meet the Sustainable Development Goal (SDG 7) of the UN. By 2030, SDG 7 aims to ensure that everyone on the planet has access to affordable, modern, sustainable and reliable energy. In addition, it seeks to increase the share of renewable energy in the world's energy mix, achieve 100% energy efficiency, and create the technologies and infrastructure needed to supply modern sustainable energy by 2030. Determining the underlying reasons for the disparities between countries and territories is essential for achieving Sustainable Development Goals and averting a catastrophe.

Sub-Saharan Africa faces substantial challenges in achieving sustainable development, which is hindered by the combination of high poverty rates, inadequate infrastructure and environmental degradation. While clean energy and financial development are recognised as essential components for advancing sustainability, existing research has predominantly examined these factors in isolation rather than exploring their combined effects. Clean energy is pivotal for addressing environmental concerns, such as deforestation, soil erosion and climate change. Financial development is crucial for fostering economic growth, improving access to resources, and supporting sustainable investments. Despite the theoretical understanding of their individual contributions, there is a significant gap in the literature regarding the integrated impact of clean energy and financial development on sustainable development outcomes in sub-Saharan Africa. However, recent studies have not sufficiently addressed how the relationship between clean energy and financial development jointly influences sustainable development, and the focus has often been on financial development alone, neglecting the potential synergies between these factors (Bei and Wang, 2023; Dutta and Saha, 2023; Obobisa, 2024; Ozili and Lorembor, 2024; Zahoor et al. 2022). Considering the existing gap, the following three research questions are raised to examine the sustainable development of sub-Saharan African nations through clean energy and financial development.

RQ1: To what extent does clean energy impact sustainable development in sub-Saharan Africa?

RQ2: How can financial development contribute to sustainable development in sub-Saharan Africa?

RQ3: How does the relationship between clean energy and financial development affect sustainable development in sub-Saharan Africa?

This research seeks to address this critical gap by investigating how the combined impact of clean energy and financial development influences sustainable development in sub-Saharan Africa. This study aims to provide a comprehensive understanding of how advancements in these areas can collectively contribute to economic growth, environmental sustainability and social inclusivity. By examining the integrated effects of clean energy investments and financial system enhancements, this study offers valuable insights for policymakers and stakeholders striving to achieve sustainable regional development.

Research Hypotheses

To facilitate comprehensive analysis, this study tested the following hypotheses to effectively steer the achievement of the study's objectives:

H₀₁- There is no significant impact of clean energy on sustainable development in sub-Saharan Africa.

H₀₂- Financial development has no significant impact on sustainable development in sub-Saharan Africa.

H₀₃- Clean energy and financial development have no significant impact on sustainable development in sub-Saharan Africa.

2. Literature review

The exploration of clean energy and financial development in sub-Saharan Africa has become a focal point in academic research given its essential contributions to alleviating energy poverty, tackling environmental issues, and promoting economic advancement in the region. Researchers have also contributed to the literature on clean energy and financial development. The relationship between sustainable development and renewable energy has received increasing attention in academia. Very few studies have attempted to study this connection in the current body of literature. Between 1995 and 2020, Hanif et al. (2022) investigated how fossil fuel and renewable energy resources contribute to sustainable development in G-7 countries. A CS-ARDL study found that clean energy had a positive impact on development during the study period, while fossil fuel energy has the opposite effect. Güney (2019) looked at the role of fossil fuels and clean energy sources in sustainable development. This analysis was built on data acquired between 1990 and 2014 from both industrialised and developing nations. Pooled Ordinary Least Squares (OLS) and System Generalized Method of Moments (GMM) estimation methods were used to investigate the effects of fossil fuels and clean energy on sustainable development. The findings revealed that clean energy has a beneficial impact on sustainable development, but fossil fuel energy has a negative impact.

Considerable research on clean energy and financial development has been conducted in Latin America. Ponce et al. (2021) studied the long-term relationship between economic growth, financial development, non-renewable energy, renewable energy, and human capital across 16 Latin American countries from 1988 to 2018. Using panel data and second-generation econometric techniques, this study found a long-term equilibrium linking these factors. Notably, the study demonstrated that the increased consumption of renewable energy does not hinder economic growth; instead, a 1% increase in renewable energy consumption is associated with a 1% increase in economic growth. These findings underscore that renewable energy consumption can support economic growth while mitigating environmental degradation. This study recommends policy measures to promote green energy and human capital as key components for sustainable economic development in Latin America. Zahoor et al. (2022) examined the impact of clean energy investment and financial development on environmental sustainability and China's economic growth from 1970 to 2016, incorporating manufacturing value added and urbanisation as moderating variables. Advanced econometric methods, including structural break unit root tests and various least squares regressions, were used for the long-run estimates. The study found that clean energy investment is negatively associated with CO₂ emissions and the ecological footprint, while positively affecting economic growth. In contrast, financial development, value-added manufacturing, and urbanisation are linked to higher CO₂ emissions and ecological footprints, but also to increased economic growth. The research highlighted that, while clean energy investment improved environmental sustainability, it does so at the cost of economic growth. Conversely, financial development and industrial factors support economic growth, but adversely impact environmental sustainability. Local governments have been urged to address barriers to clean energy and promote green finance strategies.

Similarly, clean energy and financial development have been implemented in Asia. Sadiq et al. (2022) focused on how green finance and financial development foster green economic growth in South Asia, with a particular emphasis on clean energy deployment. Using the Ordinary Least Squares (OLS) analysis from 1995 to 2018, this study examined the long-term relationships between carbon footprints, R&D investment, and green finance. The findings revealed that clean energy and green finance significantly contribute to sustainable economic practices. The study highlighted that R&D expenditures positively impact green finance development, with a 1% increase in R&D expenditures correlating with a decrease in environmental sustainability of 0.070% to 0.080%. These results underscore the importance of green bonds, reducing greenhouse gas emissions, and promoting green finance through green economic development. This study proposes a more effective path for South Asia to achieve a greener economy, emphasising the role of green finance and innovation in sustainable growth.

Ahmed et al. (2022) calculated the relationship between financial and sustainable growth in South Asian nations between 2000 and 2018. To explore this relationship in the countries under consideration the researchers used both FMOLS and DOLS estimation approaches. The findings revealed a significant positive association between financial growth and sustainable development in the studied countries. Chen et al. (2022) estimated the contribution of renewable energy sources to GDP-measured sustainable economic development throughout the 1992-2018 period. They investigated eight Asian countries. The AMG estimation technique shows that the use of renewable energy benefits economic development. Noor et al. (2023) conducted a thorough review of economic statistics for South Asia from 1995 to 2019. The main objective of this study was to examine the significance of clean energy sources and other forms of energy in relation to sustainable development. The study found that various forms of energy aid the advancement of sustainable development across countries by using the panel autoregressive distributed lag (ARDL) estimate method. The next section discusses the theoretical underpinnings of this study.

3. Theoretical Framework

The theoretical framework for this study has also been employed by Ibrahim and Alagidede (2018), Dimnwobi et al. (2022), Guei and Choga (2022) and Sinha et al. (2023) in their various studies of clean energy, green finance, and renewable energy as they relate to financial development, economic growth and sustainable development: this is the finance-led growth theory articulated by Patrick H. Tooth in 1966. This theory posits that a robust financial system is essential for fostering economic growth by fulfilling several key functions, such as mobilising and allocating funds, managing risks, enforcing corporate governance, and facilitating trade and contractual agreements. Tooth's finance-led growth theory argues that, when a financial system operates efficiently, it channels savings into productive investments, supports technological advancement, and stimulates economic expansion. This theory underscores the importance of financial systems in reducing transaction costs, managing risks, and providing oversight, all of which are critical for nurturing economic initiatives and innovations.

This theory is highly pertinent in the context of sub-Saharan Africa, where the economy is marked by high poverty rates, inadequate infrastructure, and environmental degradation. The region struggles with energy poverty and relies heavily on inefficient, environmentally harmful energy sources. The theory's relevance lies in its capacity to explain how financial development can facilitate investment in clean energy technologies. A developed financial system can mobilise capital for clean energy projects, manage the risks associated with such investments, and ensure that resources are allocated efficiently to address energy needs and environmental concerns. Clean energy projects often require substantial upfront investments and long-term financing, which can be challenging in regions with underdeveloped financial systems. By applying finance-led growth theory, this study explores how improvements in financial development, such as better access to capital, enhanced risk management tools, and stronger corporate governance, can support the adoption and expansion of clean energy technologies in sub-Saharan Africa. Such advancements can drive economic growth by creating jobs, enhancing infrastructure, and promoting sustainable practices.

Moreover, this theory highlights the role of financial systems in supporting innovation. In sub-Saharan Africa, where innovative solutions are critical for addressing energy access and environmental challenges, a well-developed financial sector can provide the necessary resources and risk management tools to foster clean energy innovations. Effective financial systems can also enhance transparency and accountability in the implementation of clean energy projects, ensuring that investments contribute to sustainable development goals. By integrating finance-led growth theory into the study of clean energy and financial development, this study aims to provide a comprehensive understanding of how these factors interact to drive sustainable development in sub-Saharan Africa. This approach offers valuable insights for policymakers and stakeholders seeking to leverage financial development to support clean energy initiatives and achieve long-term economic and environmental sustainability. The next section discusses the methods and measurement variables used in this study.

4. Methods

This study employed an ex post facto research approach to examine the links between clean energy availability, financial development, and sustainable development in sub-Saharan Africa. This technique enabled systematic data collection, statistical analysis, and hypothesis testing. A cross-sectional approach was used to gather data simultaneously from many nations in sub-Saharan Africa. This approach provided a snapshot of the interactions between independent and dependent variables, making it appropriate for analysing the region's present level of energy access, financial development, and sustainable development results. All the datasets employed in this study were obtained from the World Bank's World Development Indicator (WDI) published in 2022. This study employed an ex post facto research approach to examine the links between clean energy, financial development, and sustainable development in sub-Saharan Africa. This technique enables systematic data collection, statistical analysis and hypothesis testing. The study used a panel cointegration approach to gather data from multiple nations in sub-Saharan Africa. This approach enhances statistical power by integrating the time series and cross-sectional dimensions and allows for comprehensive comparisons across countries.

Sample size and sample technique

Sub-Saharan Africa has a total composition of 48 nations (WDI, 2023), of which 29 served as the sample size. Given the magnitude of this research, the emphasis was on analysing aggregate data at the national level rather than individual data. The sub-Saharan African nations were selected by stratified random sampling. To ensure coverage from a range of angles, the region was split into geographical sub-regions, such as East Africa, West Africa, Central Africa and Southern Africa. The nation states were randomly selected from every stratum to compose the sample. The sample size was 29 countries.

Measurement of variables

Clean energy: This indicator shows how far a nation has progressed with renewable energy. The installed capacity of renewable power generation was used as a substitute for this variable. The renewable energy variable does not account for the installed hydropower capacity. Hydropower, as an energy source, has been actively sponsored by governments for many years. As such, hydropower distorts the development of renewable energy (REN21, 2015).

Financial development (Findex, access index and depth index): This variable gauge the financial development of a nation. Three composite indicators were used as proxies for the variables: access, depth and the financial development of financial institutions. See Svirydzienka (2016) for more details on the construction of these indices. The goal of using composite indices is to circumvent the challenges that arise when using a single dimension indicator, such as automated teller machines (ATMS) per 100,000 people or private sector credit to GDP. The advancement of a nation's financial sector was monitored by the financial development index. This multifaceted metric assesses the breadth, accessibility and effectiveness of the financial sector. Capital markets, insurance and banking are represented by indices.

The ratios of private sector credit to GDP, pension fund assets to GDP, mutual fund assets to GDP, and life and non-life insurance premiums to GDP were used to generate the financial institutions depth index. According to the World Bank (2008), deep financial systems are effective in allocating funds for their most advantageous uses. Additionally, they look for and finance solid development opportunities wherever they may present themselves, as well as offering savings, payments and risk management solutions to as many participants as possible (Beck et al. 2008). The number of automated teller machines (ATMs) per 100,000 people and the number of commercial bank branches per 100,000 people were used to compute the access index of financial institutions. According to the International Monetary Fund (2011), people with more access to money have more opportunities. Furthermore, the utilisation of banking services is connected to decreased funding barriers for both individuals and enterprises. The SSA population has restricted access to both relative and absolute financial services. Lack of access to capital is a major impediment to the expansion of small and medium-sized firms in SSA (IFC, 2013). Financial development factors are projected to connect favourably with the renewable energy production variables.

Real GDP per capita: This is a proxy for a country's income per capita. This variable is projected to have a positive correlation with renewable capacity. Countries with greater income levels are likely to invest in renewable energy sources.

Foreign direct investment (FDI): This variable represents the net inflow of foreign direct investment into a nation. FDI boosts renewable energy installation capabilities. FDI also facilitates technological transfer from developed to developing nations (Blalock and Gertler, 2008; Findlay, 1978). This variable is projected to have a positive correlation with renewable installed capacity. This study evaluated a country's annual energy consumption from both renewable and non-renewable sources. The consumption variable served as a proxy for a country's electricity demand. This variable is projected to correlate favourably with renewable installed capacity.

Imports: This variable quantifies the annual volume of electricity imported by the nation. Dependence on imported energy adversely impacts investment in domestic energy generation capacity. Consequently, this variable is anticipated to exhibit a negative correlation with the installed capacity of renewable electricity.

Table 1: Measurement of variables

Description of variables and their data sources variables	Measurement	Data source
Sustainable development	GDPPC = GDP per capita (current US\$)	Moiseev et al., (2020)
Financial development	Index comprising of liquid liabilities (percent of GDP), domestic credit to private sector (percent of GDP), and broad money (percent of GDP)	Anton and Nucu (2020)
Clean energy	Renewable energy (quadrillion btu)	Hosseini and Wahid (2020).
Nonrenewable energy	Nonrenewable energy (quadrillion btu)	Güney (2019)
Foreign Direct Investment (FDI)	A share of GDP in country i at period t	FDI markets database

Model specification

To achieve the study objectives, the model proposed by Ponce et al. (2021) was adapted. Ponce et al. (2021) investigated the impacts of financial development, clean energy, and human capital on sustainable growth in Latin America. The model employed is stated thus:

$$GDP_{it} = \beta_0 + \beta_1 FD_{it} + \beta_2 NREC_{it} + \beta_3 REC_{it} + \beta_4 HC_{it} + \varepsilon_{it} \dots \dots \dots (1)$$

Where:

GDP = logarithm of economic growth,

FD = logarithm of financial development,

NREC = logarithm of non-renewable energy consumption,

REC = logarithm of renewable energy consumption,

HC = logarithm of human capital,

β_0 = constant term,

β_{1-4} = coefficients of the independent variables and

ε = error term.

Therefore, the above model is adjusted to achieve objectives 1 and 2 of this study as follows:

$$GDPPC_{it} = \beta_0 + \beta_1 FD_{it} + \beta_2 CE_{it} + \beta_3 UNEMP_{it} + \beta_4 FDI_{it} + \beta_5 TO_{it} + \beta_6 FD * REC_{it} + \varepsilon_{it} \dots \dots (2)$$

Where:

GDPPC = GDP per capita (current US\$),

FD = Financial Development (Domestic credit to private sector by banks (% of GDP),

CE = Renewable energy consumption (% of total final energy consumption),

UNEMP = Unemployment, total (% of total labor force) (modeled ILO estimate),

FDI = Foreign direct investment, net (BoP, current US\$),

TO = Trade openness (Trade (% of GDP)),

FD*RE = Interaction of Financial Development and Renewable Energy (Product of FD and RE) and

ε = error term.

The next section discusses various statistical tests and their results to investigate how the combined impact of clean energy and financial development influences sustainable development in sub-Saharan Africa.

5. Results

This section presents the empirical results of this analysis. The analysis of the data starts with the presentation of descriptive statistics, then the unit root test of all the variables used, and finally, the FMOLS regression results.

Descriptive statistics

Table 2: Descriptive statistics

	FD	FD*CE	FDI	GDPPC	CE	TO	UNEMP
Mean	22.1647	937.1682	-4.95E+08	1786.476	64.0294	67.4144	9.3352
Median	14.2501	847.1003	-97739080	913.3087	72.2800	59.2273	5.6840
Maximum	171.4214	3492.249	8.75E+09	11643.46	96.0400	175.7980	37.9400
Minimum	0.0016	0.1408	-2.51E+10	114.3670	7.7200	20.7225	0.3200
Std. Dev.	27.9080	570.8019	1.83E+09	2085.569	23.7347	28.9261	8.2830
Skewness	3.2503	0.7523	-5.584202	2.079332	-0.7203	1.0175	1.3417
Kurtosis	14.0582	3.5582	65.05224	7.202065	2.3749	3.6975	3.9269
Jarque-Bera	6060.601	99.4878	144432.8	1351.471	95.3520	178.9517	311.6348
Probability	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Sum	19593.63	868755.0	-4.31E+11	1657850.	59419.31	62560.60	8663.124
Sum Sq. Dev.	687728.0	3.02E+08	2.92E+21	4.03E+09	522211.7	775637.3	63599.62
Observations	884	927	872	928	928	928	928

Source: Author's computation (2024)

Descriptive analysis provides valuable insights into the distribution characteristics of the variables under consideration. In exploring each variable's characteristics, tendencies and implications as used in this study, the results show, for the variable "Financial Development (FD)", that the descriptive statistics reveal a wide range of values, with a mean of 22.1647 and a maximum of 171.4214. The skewness value of 3.2503 indicates a heavily right-skewed distribution, suggesting that a few observations have considerably high values. This skewness is further supported by the high kurtosis value of 14.0582, indicating a distribution with a pronounced peak and heavy tail. Such characteristics suggest that the distribution of financial development is not asymmetrical and may exhibit outliers or extreme values, potentially warranting further investigation. The interaction of financial development and clean energy consumption (FD*CE) show a mean value of 937.1682, suggesting a substantial average level. However, the relatively high standard deviation of 570.8019 indicates considerable variability around this mean. The skewness value of 0.7523 suggests a slight right skew, while a kurtosis value of 3.5582 indicates a distribution that is slightly heavier tailed than normal. These findings imply that the interaction between financial development and renewable energy consumption exhibits some degree of variation, with potential implications for sustainable development initiatives and economic policy planning.

Foreign direct investment (FDI) shows distinctive characteristics, with a negative mean value of -4.95E+08, indicating an overall negative average level across observations. The highly negative skewness value of -5.5842 and the extremely high kurtosis value of 65.0522 suggest a heavily left-skewed distribution with a high peak and heavy tails. Such distributional properties imply that foreign direct investment experiences significant variability across observations, and is potentially influenced by economic, political and regulatory factors. The departure from normality, as indicated by the Jarque-Bera test statistic of 144432.8, underscores the need for robust modelling techniques when analysing the FDI data. The GDP per capita (GDPPC) reflects the economic well-being of a country's population and exhibits notable distributional characteristics. With a mean value of 1786.476 and a wide range of values spanning from 114.3670 to 11643.46, the GDPPC demonstrates considerable variability across observations. The positive skewness value of 2.0793 and the high kurtosis value of 7.2021 suggest a right-skewed distribution with pronounced peaks and a heavy tail.

Clean energy consumption (CE) and trade openness (TO) display distinct distribution patterns. RE exhibits a moderate average level with a mean of 64.0294, while TO demonstrates a higher average level with a mean of 67.4144. Skewness values of -0.7203 for RE and 1.0175 for TO indicate slight deviations from symmetry, with RE slightly skewed to the left and TO slightly skewed to the right. Additionally, kurtosis values of 2.3749 for RE and 3.6975 for TO suggest distributions with relatively lighter tails than normal, albeit with some degree of peakedness. Finally, unemployment (UNEMP) reveals a moderate average level with a mean of 9.3352. A positive skewness value of 1.3417 indicates a right-skewed distribution, suggesting that unemployment rates are skewed towards lower values. A kurtosis value of 3.9269 suggests a distribution with heavier tails than normal, implying potential outliers or extreme values.

Unit root test

The rationale for conducting a stationarity test lies in the inherent non-stationarity of time-series data, where values tend to diverge from their mean over time, potentially leading to unreliable regression results when analysed using Ordinary Least Squares (Gujarati, 2008). In the context of panel data, which includes both time and space components, the variables were tested for stationarity using the Augmented Dickey-Fuller (ADF) Test for Unit Root. The null hypothesis of the ADF test proves the

presence of a unit root, indicating non-stationarity. If the p-value of the ADF statistics is less than 5%, the null hypothesis is rejected, indicating stationarity.

Table 3: Panel Stationarity Test using ADF Test

Augmented Dickey-Fuller Test (Fisher Chi-square)			
Variable	Level	First Difference	Decision
FD	42.0843 (0.9425)	298.529 (0.0000)	I(1)
CE	52.3495 (0.6845)	310.072 (0.0000)	I(1)
FD*CE	51.0466 (0.7293)	309.488 (0.0000)	I(1)
TO	66.7836 (0.2008)	393.436 (0.0000)	I(1)
UNEMP	49.0734 (0.7918)	287.634 (0.0000)	I(1)
GDPPC	19.2918 (1.0000)	345.524 (0.0000)	I(1)
FDI	102.599 (0.0003)	NA	I(0)

Source: Author's computation (2024)

For the variable "Financial Development (FD)," the ADF test statistics for the original series indicate a lack of stationarity, with a value of 42.0843 and a corresponding p-value of 0.9425. However, after differencing the series once to remove any trends, the ADF test statistic decreased significantly to 298.529, accompanied by a p-value of 0.0000. This result suggests that after differencing once, the series becomes stationary, as denoted as "I(1)". In addition, Clean Energy Consumption (CE) has similar findings. The original series exhibits non-stationarity, as evidenced by an ADF test statistic of 52.3495 and a p-value of 0.6845. Nevertheless, after differencing the series, the ADF test statistic notably decreased to 310.072, with a corresponding p-value of 0.0000, indicating stationarity at the first difference level I(1). Similarly, the interaction between financial development and clean energy consumption (FD*CE) follows a comparable pattern. The initial ADF test statistic is 51.0466, with a p-value of 0.7293, suggesting non-stationarity. However, after differencing the series, the ADF test statistics substantially decreased to 309.488, accompanied by a p-value of 0.0000, signifying stationarity at the first difference level.

The variable "Trade Openness (TO)" also exhibits a similar pattern. The original series displays non-stationarity, with an ADF test statistic of 66.7836 and p-value of 0.2008. Nonetheless, after differencing the series, the ADF test statistic decreased significantly to 393.436, with a p-value of 0.0000, indicating stationarity at the first difference level. Furthermore, "Unemployment (UNEMP)" and "GDP per capita (GDPPC)" demonstrate analogous outcomes. The original series of both variables shows non-stationarity, with ADF test statistics of 49.0734 and 19.2918 respectively, and corresponding p-values above 0.05. However, after differencing the series, the ADF test statistics decreased notably, accompanied by p-values of 0.0000, indicating stationarity at the first difference level. Conversely, "Foreign Direct Investment (FDI)" presents a different scenario. The original series exhibits stationarity, as indicated by an ADF test statistic of 102.599 and a p-value of 0.0003, suggesting no need for differencing. In conclusion, the ADF test results show that six (6) out of the seven (7) variables were stationary at first difference (FD, CE, FD*CE, TO, UNEMP and GDPPC), while one (FDI) was at level decision.

Estimates from fully modified ordinary least square (FMOLS)

Table 4: Panel regression analysis result

Panel Fully Modified Least Squares (FMOLS) Dependent Variable: GDPPC (GDP per capita (current US\$))			
Variables	Coefficient	t-Statistic	Probability
FD	93.23060	12.38422	0.0000
CE	-17.12731	-2.760178	0.0059
FD*CE	-0.821570	-4.982361	0.0000
TO	-12.61303	-4.845460	0.0000
UNEMP	5.705089	0.240363	0.8101
FDI	-7.97E-08	-3.222679	0.0013
R-squared	0.887017	Mean dependent var	1867.840
Adjusted R-squared	0.881963	S.D. dependent var	2168.732
S.E. of regression	745.1018	Sum squared resid	4.22E+08
Long-run variance	1219444.		

Source: Author's computation (2024)

The results of the panel Fully Modified Least Squares (FMOLS) regression provide valuable insights into the factors influencing GDP per capita (GDPPC), a key indicator of sustainable development. This analysis considers a comprehensive set of independent variables, allowing us to understand the complex dynamics shaping sustainable development across different regions and periods. First, the coefficient estimate for Financial Development (FD) stands out as particularly significant. With a positive coefficient value of 93.23060 and a high t-statistic of 12.38422 (p-value < 0.0001), these results suggest a strong positive relationship between financial development and GDP per capita, which is a proxy for sustainable development. However, the impact of clean Energy Consumption (CE) on GDP per capita presents an interesting dynamic. The coefficient estimates of -17.12731 and a probability value of 0.0059 suggest a negative and statistically significant relationship between CE and GDPPC. Moreover, the interactive effect between Financial Development and Clean Energy (FD*CE) is noteworthy. With a coefficient estimate of -0.821570 and a significant t-statistic of -4.982361 (p-value < 0.0001), the results suggest that the combined impact of FD and CE on GDP per capita is negative. Additionally, the coefficients for Trade Openness (TO) and Foreign Direct Investment (FDI) also demonstrate notable impacts on GDP per capita.

The negative coefficient of TO (-12.61303) suggests that higher levels of trade openness may have a detrimental effect on economic growth, possibly due to increased exposure to external shocks or competition. Conversely, the negative coefficient for FDI (-7.97E-08) implies that higher levels of foreign direct investment may lead to lower GDP per capita, which could be attributed to factors such as resource dependency or the unequal distribution of benefits. It is essential to note that the regression model exhibited a high degree of explanatory power, as indicated by the R-squared value of 0.887017. This finding suggests that approximately 88.7% of the variation in GDP per capita can be explained by the independent variables included in the model. Moreover, the adjusted R-squared value of 0.881963 accounts for the degrees of freedom and provides a more accurate measure of the model's goodness-of-fit, considering the number of predictors.

6. Discussion

The results of the panel Fully Modified Least Squares (FMOLS) regression show that the positive significant finding of the relationship between financial development and sustainable development aligns with economic theory, indicating that a well-developed financial sector, characterised by efficient credit allocation and investment facilitation, positively impacts economic growth by providing businesses and individuals with access to capital for productive activities. This finding is in line with the studies of Gharleghi and Jahanshahi (2020), and Hussain et al. (2021) and is in opposition, with regards to the direction of impact, to the studies of Ozili and Iorember (2024), and Dutta and Saha (2023). Meanwhile the effect of clean energy consumption on sustainable growth is shown to be negative and significant, which is in line with the study of Steve et al. (2022) but is in opposition to the study of Gogu et al. (2021), Riti et al. (2022) and Ofori et al. (2023). While this may seem counterintuitive given the global push towards renewable energy adoption for sustainable development, it is essential to consider the potential factors at play. The negative coefficient could indicate challenges associated with the transition to renewable energy, such as initial investment costs or technological constraints, which may temporarily dampen economic growth in the context of this study. Nonetheless, the results reveal the importance of conducting further investigation into the nuanced relationship between renewable energy adoption and sustainable development. Furthermore, the significant negative combined impact of financial development and renewable energy on sustainable development implies that, while each factor may individually contribute positively to economic growth, their joint effect exhibits a mitigating influence. Understanding the mechanisms underlying this interaction could provide valuable insights for policymakers seeking to balance economic development with environmental sustainability goals. The pronounced negative correlation between renewable energy consumption and external shocks highlights the need for comprehensive policies and strategies to advance and maintain renewable energy consumption. Consequently, it is crucial to sustain steady investment in renewable energy infrastructure, even amid economic instability, to ensure long-term environmental sustainability. The notable negative impacts of financial development and renewable energy on sustainable development align with finance-led growth theory. This alignment underscores the necessity of considering various factors and potential trade-offs when formulating strategies to promote sustainable economic growth through long-term financial development and renewable energy initiatives. This finding is in line with the studies of Ibrahim and Alagidede (2018), and Dimnwobi et al. (2022), who also found a significant negative impact of financial development and renewable energy on sustainable development, particularly in the long run.

The analysis also reveals the negative impact of trade openness on sustainable development, suggesting that increasing exposure to international trade might harm the economy, possibly due to vulnerabilities to external economic shocks or heightened competition that domestic industries may not be prepared for. This finding is consistent with that reported by Abassi et al. (2022). This indicates that, while trade openness can offer opportunities for market expansion and efficiency gains, it might also bring risks that outweigh the benefits if the economy is not adequately diversified or resilient. Similarly, the negative effect of foreign direct investment on sustainable development suggests that higher levels of foreign direct investment do not necessarily translate to sustainable development. This counterintuitive result could be due to several factors, such as a heavy reliance on foreign investments in specific sectors such as natural resources, which might not create widespread economic benefits. Additionally, the benefits of FDI may be unevenly distributed, failing to significantly uplift the broader economy or improve per capita income. Furthermore, the findings on the impact of financial development on sustainable development are positive and significant. The high explanatory power of the regression model, indicated by the R-squared value, shows that the independent variables collectively explain a substantial proportion of the variation in GDP per capita. This suggests that the chosen predictors are highly relevant and provide a robust framework for understanding the economic growth dynamics. The adjusted R-squared value, which adjusts for the number of predictors in the model, also indicates strong goodness-of-fit, reinforcing the reliability of the model's findings.

7. Conclusion

In conclusion, the findings of this study underscore the intricate relationship between clean energy availability, financial development, and sustainable development in sub-Saharan Africa. Despite facing significant challenges, such as energy access disparities and financial underdevelopment, the region holds immense potential for achieving sustainable growth and improving people's well-being. This study highlights the importance of addressing the barriers to clean energy adoption and enhancing financial inclusion to unlock this potential. Clear and consistent policies that incentivise investment in clean energy, coupled with reforms to strengthen the financial sector, are essential for fostering sustainable development. Innovative financing mechanisms and capacity-building initiatives can mobilise capital for clean energy projects while promoting economic growth and social equity. Moreover, the nuanced dynamics revealed by regression analysis emphasise the need for tailored approaches that balance economic development with environmental sustainability goals. By understanding the complex interplay between clean energy, financial development, trade openness, and foreign direct investment, policymakers can formulate targeted strategies to address key challenges and capitalise on opportunities for sustainable development. Ultimately, by investing in clean energy infrastructure, promoting financial inclusion, and implementing supportive policies, sub-Saharan Africa can overcome its development challenges and chart a path towards a more sustainable and prosperous future for all its inhabitants.

Based on the results of the panel Fully Modified Least Squares (FMOLS) regression, several policy recommendations can be formulated to promote sustainable development in sub-Saharan Africa. First, given the significant positive relationship between financial development and GDP per capita, policymakers should prioritise initiatives aimed at strengthening the financial sector. Second, despite the negative coefficient estimate for Renewable Energy Consumption (RE), policymakers should continue to prioritise clean energy adoption as part of sustainable development efforts. To overcome the challenges associated with renewable energy transition, targeted policies should be implemented to address investment barriers, such as high initial costs and technological constraints. Third, policymakers should enhance institutional frameworks, capacity building and financial resources, and cultivate favourable political environments to attract investors and alleviate financing constraints in the renewable energy sector. Fourth, it is crucial for policymakers to prioritise reforms that promote stakeholder collaboration and integrated development and ensure robust governance to effectively address the challenges faced. Fifth, policymakers should focus on implementing trade policies that promote economic diversification, protect domestic industries from external shocks or competition, and foster regional integration initiatives to enhance intra-regional trade. Finally, the negative coefficient estimate for Foreign Direct Investment (FDI) implies that higher levels of FDI may lead to lower GDP per capita in sub-Saharan Africa. Therefore, policymakers should carefully evaluate FDI inflows to ensure that they contribute to sustainable development objectives.

Suggestion for future studies

Due to the large mass of missing data in the sub-Saharan sub-region of Africa, this study suggests that future studies be carried out using related variables with available data, and that the period that is investigated should be increased. Future studies could also be conducted in other regions where data is available. Other analytical methods can be employed to determine whether the same directional effect and significance are attained, thereby strengthening the findings of this study for the adoption of recommendations.

Declarations:

- Originality statement: I, Saidu MUSA, confirm that this manuscript is original, has not been previously published, and is not under review elsewhere.
- Author approval statement: I, Saidu MUSA, confirm that all authors have read and approved the submitted manuscript, and the author order has been agreed upon by all co-authors.
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