



Attaining Sustainable Development in Africa through Renewable Energy Financing

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ABSTRACT

Finding a sustainable solution to climate change based on the unique attributes of Africa requires some well-structured bespoke green financial vehicles that will spur development not only from economic standpoint but also in the quality of the environment and social wellbeing of the populace. This study therefore examines the role renewable energy financing in harnessing sustainable development in Africa. The study thus employed the panel ARDL estimation technique to analyse this relationship while limiting the sample size to limited to Nigeria, South Africa, Kenya and Egypt representing countries with significant renewable energy investment from 1990 to 2023. Findings depict that in the short run, insignificant relationships were found between renewable energy utilisation and economic sustainability as well as between renewable energy utilisation and environmental sustainability. However, in the long run, the relationships are revealed to be both negative but statistically insignificant for economic sustainability but significant for environmental sustainability. The substantial negative effect of renewable energy usage on carbon emissions follows worldwide expectation and reflects clean energy as a solution to environmental deterioration. This study recommend that government should utilize both fiscal and monetary instrument to encourage renewable energy investment in Africa. This can be in the form of tax incentive and grant on green project that are executed in Africa. Foreign direct investment should be channelled to green project that promote skill enhancement and sustainable workforce. The use of tailored regulation to create a renewable energy market for local and foreign investor and at the same time creating an unfavourable environment for investment in fossil fuel in Africa.

Keywords: Sustainability, Climate Change, Renewable Energy Financing, Carbon Emission, Sustainable Development Goals, Africa

JEL Classifications: Q01, Q43, Q54, O16, J24

1. INTRODUCTION

As planet earth continue to get hotter, the negative consequences of climate change become more inescapable to its occupants. This is based on the premise that industrial production and household consumption requires the use of various energy and natural resources which are associated with greenhouse gases emission and hence a reoccurring cycle of global warming. The need for the protection and preservation of mother earth from climate change has, thus, birthed various sustainability movement in recent years both in practice and in policies. The dynamic nature

of climate changes makes it difficult to provide one-off solution in the short run. The basic needs of man in terms of food, clothing and shelter are at greater risk now than ever due to the negative consequences of climate changes. Undoubtedly, climate change over the years has led to greater uncertainty in food production across the globe due to constant drought in some areas and reoccurring flood in other areas as well as increasing geopolitical water related conflict. Furthermore, plants and pest are becoming more resistance to herbicides and pesticides respectively which posed a greater threat to global food security. Africa is at the receiving end of the negative consequences of climate change

due to its unique adaptive capacity. Millions of livelihoods in Africa are predominantly dependent on primary production and extractive sector which are worst hit by climate change, and this posed a more worsening threat to economic stability and peace in the continent (FAO, 2020; Nhemachena, 2020; Ofori et al., 2021; Froehlich et al., 2022; Sun et al., 2023).

Globally, myriads of actions have been taken by various stakeholders to curb the negative consequences of climate changes. From the 1972 Stockholm earth summit to the 1992 climate change convention of the United Nation to the 1997 Kyoto carbon protocol to the 2015 Paris climate accord and more recently the United Nations seventeen sustainable developmental goals. Environmentally responsible nations have also initiated a number of structured policies towards climate resilience. In Europe, Germany and Turkey embarked on renewable energy vision 2021 and 2023 respectively. In Asia, China initiated carbon neutrality by 2060 while Japan targeted 2050 to attain net-zero greenhouse gases emission. Similarly, South Korea implemented its energy master plan to be attained before 2035 while Singapore target 2030 to actualise its green plan. In the middle east, The United Arab Emirate and Qatar also initiated their national energy strategy to be actualised by 2050 and 2030 respectively. Notwithstanding, the above-mentioned policies, strategies and vision to combat climate changes by various nations across the globe are exclusively subject to sufficient funding for their successful implementation and actualisation (Sun et al., 2023).

The utilisation of fossil fuel to power the global economy in the last decades is highly linked to the chief drivers of climate change and its negative consequences such as reduce life expectancy (Osabohien et al., 2021). Despite the awareness of the negative environmental consequences of the utilisation of fossil fuel, most developing and under developing economies across the globe remain handicapped as regards the transition to clean energy utilisation due to absence of sufficient financing vehicle available to harness such transition (Asemota and Olokoyo, 2022). Africa has untapped deposit of renewable energy resources from solar to wind to biomass to oceanic to geothermal and nuclear energy sources that if sufficiently harness and financed through green financial vehicles could sustainably combat climate changes threats in the continent. In 2021, the International Energy Agency estimated that the transition to clean energy utilisation in Africa will require over four trillion dollars' investment from both private and public sector. Furthermore, more than ninety-five million dollars has been sunk into renewable energy financing by the Africa Development Bank through the sustainable energy fund for Africa (SEFA) since inception in 2011. Despite these funding in the last decades, Africa continue to utilise fossil fuel to power majority of its productive sector while the renewable energy sources remain underutilised. Hence the need to investigate the challenges as well as the impact of these renewable energy funds on various aspect of sustainability in Africa. Myriads of empirics are available on renewable energy financing across the globe, but this study is a unique attempt in Africa to provide new evidence on how sustainable development can be harnessed through renewable energy financing in the continent through the lenses of carbon emission reduction, Human capital development and

capital market development. The structure of the other sections of this study includes the conceptual and theoretical review of relevant literature on renewable energy finance; the methodology utilized to achieve the study objective, the findings and implication of findings from the data analysis, and the concluding part with relevant policy implications and recommendations to climate stakeholders in Africa.

2. LITERATURE REVIEW

2.1. Concept of Renewable Energy Financing

Renewable energy finance connotes all coordinated activities towards the acquisition, equitable allocation, efficient utilization and timely retirement of relevant funds for the development, distribution, marketing and consumption of renewable energy-related products, services and technology. Zhang (2018) views energy financing as the interrelationship of energy financial markets, energy pricing mechanisms, corporate energy financing, green investment, energy derivatives market and energy risk management.

Renewable energy financing also entailed mechanisms aimed at harnessing energy-led economic growth and development. The categorisation of renewable energy financing can be influenced by the intrinsic nature and source of finance, financial market, product and institution, international or local regulatory and monetary authorities, and the private and public led sectors.

2.2. Concept of Renewable Energy

Even before the signing of the Paris Climate Change Agreement in 2015, major economies across the globe have been making tremendous drives to move from non-renewable energy to completely clean energy in their energy basket. Cai et al. (2018) argue that renewable energy sources are quite expensive and less accessible than non-renewable energy sources, which sometimes contributes to policy myopia between the reduction of carbon emissions and efficient growth of the economy. Clean energies are non-carbohydrate energy such as nuclear, hydro, solar, biomass, geothermal, wind and oceanic sources of energy. Renewable energy rarely produces greenhouse gases which favours the drive for a low-carbon economy. There is a current drive to change the energy mix of major countries to ensure renewable energy sources contribute more than seventy percent of the total energy basket. The production and consumption of clean energy significantly reduce the negative effect CO₂ emissions.

Renewable energy is all from of energy that replenish naturally with same or different proportion to the rate of consumption. The most important feature of renewable energy is the ability to not to contribute to degradation of the environment and its sustainability over time. A major drawback of fossil fuels is the release of greenhouse gases, which deplete the ozone layer and raise concerns about global climate change. The use of cleaner energy sources to power the productive sector of any economy will contribute immensely to the protection and preservation of the environment, which is the basic conduit that houses all factors of production. The utilisation of clean energy will protect both wildlife and aquatic life, air, water, and land pollution will be

minimised, and the health and well-being of human capital stock will be optimised. Green or clean energy is not entirely free from harm to the environment, but when compared to fossil fuels, they have little or insignificant contribution to global warming. In achieving goal number seven of the United Nations sustainable development agenda, renewable energy sources are the only viable avenue to ensure energy efficiency as well as universal availability, affordability and accessibility of energy and energy-related services sustainably.

2.3. Theoretical Background

2.3.1. Environmental Kuznets curve (EKC) hypothesis

In 1955, Simon Kuznets asserted that the increase in economic growth is followed by increased inequality in the economy. This increase in inequality is explained by the activities of entrepreneurs having access to cheaper factors of production, which further widens the income gap. Furthermore, with industrialisation, increased urban-rural migration and increased activities of the state to redistribute income, income inequality is further reduced with increased growth in the gross domestic product (Stern 2004, Datta and De, 2021 and Lee et al., 2024). Over the years, environmental economists have extended this theory to evaluate the nexus between the use of various natural resources, increase in economic activities and various environmental impacts.

Environmental Kuznets curve postulates that the increased use of natural resources follows significant growth in economic activities and income level, and hence, an increase in environmental pollution is evidence, and after a peak level is reached, environmental pollution begins to decline with an increase in income level and economic activities (Mahmood et al., 2023, Sarkodie and Ozturk, 2020 and Bibi and Jamil, 2021). The initial environmental pollutions are attributed to rapid industrialization, leading to increased fossil fuel demand from heavy energy-dependent factories, increased emissions from urbanization and the use of technologies that use fossil fuel, weak or absent of environmental regulatory framework, heavy reliance on fossil fuel and lack of access to cleaner technology. On the other hand, the later improvement in the environment as a result of an increase in income level is due to rapid innovation and the use of cleaner technologies that are affordable, greater environmental awareness and tougher environmental regulation, government policy through carbon tax and low-carbon subsidies, shift from heavy industry to service base industry and smart urbanisation policy. The outcome of the environmental Kuznets hypothesis, when plotted on a graph, will depict an Inverted-U-shaped curve for most developing economies (AlKhars et al., 2022; Leal and Marques, 2022).

2.3.2. Empirical review on renewable energy finance across the globe

In Algeria, Bergougui (2024) made use of both quantile and nonlinear auto regressive distributive lag technique of data analysis to examine role of renewable energy utilization, innovation in technology and utilization of fossil fuel in combating environmental degradation. The findings indicate that carbon emission decrease from positive shocks in both renewable energy and innovation in green technology while negative shocks contributed to increasing environmental degradation. On the other

hand, both positive and negative shocks in the utilization of fossil fuel greatly led to increase carbon emission during the study period between 1990 and 2021. Furthermore, the result from the quantile granger causality test depict that all the repressor under investigation has dual causal effect on carbon emission in Algeria during the study period.

Shabani (2024) Introduce the influencing role of human capital index to examine how renewable energy contribute to the fight against climate change through reduced carbon emission. Using Dumitrescu Hurlin panel causality test and threshold generalized method of moment techniques of data analysis, the study findings indicate a negative association between the utilization of renewable energy and carbon emitted for the sixteen-seven countries during the study period of 1999-2019. Human capital index for developing countries for a given threshold significantly accounted for reduce carbon emission through the utilization of renewable energy. However, developed countries experience more influencing role of human capital index by 5 times more than developing countries.

Rahman et al. (2024) focus on the major carbon emitting countries globally to understand the alleviating role of renewable energy in ensuring environmental sustainability. Having utilized the quantile method of moment technique of data analysis, their findings shows that carbon emission was highly sensitive to the utilization of renewable energy as lower rate of carbon was emitted during the study period between 1990 and 2020. On the contrary, increase production and consumption of fossil fuel, issuance of patent for manufacturing purposes and growth in the real gross domestic product greatly accounted for increasing environmental degradation for the top carbon emitting countries globally.

In china also, Zeng et al. (2024) utilized the spatial Durbin model to understand how the progress in green technology has impact the level of carbon emission during the study period between 2008 and 2020. The findings reflect a remarkable reduction in carbon emission as a result of technological progress in green technology for most region in the 30 provinces in China. However, the transmission channel through energy efficiency was more noticeable than that of structure of energy and industry. However, the provinces in the eastern region witnessed more reduction in the level of carbon emission than other region due to environmental innovation, and improved human capital stock as well as a developed market. Lastly the transmission effect of government technology has no significant effect on carbon emission in all the provinces.

In Thailand, Xuan et al. (2024), utilized a mixed method of technique of analysis comprising of regression and sensitivity analysis to investigate the impact of renewable energy, foreign direct investment and growth in urban population on the environmental degradation. The findings depict an increasing carbon dioxide emission as the growth of the urban population surge in Thailand. Furthermore, environmental quality in Thailand greatly improve through various investment from foreign bodies during the study period of 2000-2022. Lastly, the production and consumption of renewable energy in Thailand during the study period was also found to positively enhance environmental quality.

In the United states of America, Kartal et al. (2023) employed granger causality techniques of data analysis to explore the role of both nuclear and other renewable energy source in enhancing environmental sustainability. Their findings indicate that the utilization of nuclear energy in the United states during the study period of 1965-2018 has favourably contributed to the fight against climate change through carbon reduction. Similarly, the utilization of other sources of renewable energy such as solar and wind in the United States also accounted for significant portion of environmental quality witnessed during the study period. Their findings also claim that the development of the financial sector in during the study period aided environmental sustainability while the growth in the economy negatively affect ecological quality.

Adebayo et al. (2023) limited their investigation to BRICS nations to understand how environmental quality can be enhanced through renewable energy utilization and innovation in green technology thereby realizing sustainable development goals for BRICS. Engaging the auto regressive distributive lag on a cross sectional basis, their findings shows that carbon emission was mitigated both in short and long run period through the utilization of renewable energy during the study period between 1990 and 2019. For the green technological innovation and rent from natural resources, their impact also resulted in improved environmental quality through the reduction in carbon emission for BRICS during the study period.

For the seven emerging economies (E7) Ali et al. (2023) Focus their research on the impact of energy resource and financial development on carbon emission reduction for a period between 2000 and 2020. Having engage panel quantile regression techniques of data analysis, their result indicates environmental quality in the seven emerging economies was greatly improved through the utilization of renewable energy resources as well as globalization which greatly harness the attainment of the various sustainable development goals by the United Nations. On the contrary, the utilization of fossil fuel and growth in the financial sector of the seven emerging economies did not contribute to the reduction of carbon emission during the study period. Similarly, Zhang et al. (2024) for the same seven emerging economies shifted their focus to the role of nuclear energy and digitization in promoting environmental quality now measured by both ecological footprint and carbon emitted during the study period of 1996-2019. Using augmented mean group techniques of data estimation, their findings reveals that environmental sustainability was impaired by the relative development in the financial sector and overdependence on fossil fuel. On the contrary, nuclear energy and digitization accounted for sufficient progress in environmental quality in the seven emerging economies under investigation.

In central Europe, Józwick et al. (2023) utilized the Dumitrescu–Hurlin causality test and the panel autoregressive distributive lag techniques of data analysis to understand how environmental quality in terms of carbon emission can be harness through renewable energy utilization, development in the financial sector and growth in the economy. The findings from their study indicate

that economic growth in the central Europe during the study period of 1995-2019 accounted for significant increase in carbon emitted which adversely affected environmental sustainability. Furthermore, the utilization of renewable energy resources, digitization and development in the financial sector accounted for improved environmental quality during the study period.

Zhao et al. (2023) limited their investigation to the reduction of carbon lock-in for about seventy-seven countries. The principal focus was about the role of renewable energy generation consumption in combating carbon emission. Using generalized methods of moments as technique of data analysis, the findings depicts a significant reduction of carbon emission for majority of the countries under investigation during the study period from 2000 to 2020. Moreover, the utilization of geothermal energy sources generated the most significant marginal effect on carbon emission reduction. Their result also depicts the relevance of technological and scale effect as a meditating role in the fight against climate change through renewable energy consumption for the countries under investigation.

Behera et al. (2023) limited their research to about eighteen emerging countries to understand the impact of renewable energy and green technological innovation in promoting environmental sustainability through carbon neutrality. Having utilized auto regressive distributed lag on a cross sectional basis as well as the correlated mean group estimator, their findings depicts reduce carbon emission in both in the immediate and long run during the study period of 1990-2018. Furthermore, other control variables utilized for the study such as the growth in the gross domestic product, importation of energy and utilization of fossil fuel greatly accounted for increase carbon emission. On the other hand, urbanization and the fight against corruption accounted for improved environmental quality for most of the emerging countries under investigation.

Dasanayaka et al. (2022) similarly in Sri Lanka engage the structural equation model to investigating the effects of renewable energy utilization towards the economic growth for a study period 1990-2018. Their result indicates that renewable energy utilization in Sri Lanka has a positive and significant influence on economic growth.

Dimnwobi et al. (2022) similarly made use of the renowned auto regressive distributed lags estimation technique to investigate the possible causal effect between the development of the Nigeria financial sector and the contentious production and consumption of renewable energy. During the study period of 1981-2019, the result of their findings depicts that the increasing use of clean energy in Nigeria is chiefly due to the aggregated developing activities in the financial sector.

In China, Ali et al. (2022) engage the auto regressive distribute lag technique of data analysis to examine the long run connection between the reduction of carbon emissions and the utilization of both clean energy and fossil fuel. Their findings depict a long run connection between all variable of the study during their study period of 1990-2019. Furthermore, control variable such

as expenditure in research and development and technology positively contributed to the reduction of carbon emission in all the province in China. However, variable such as growth in urban population was found to account for increasing carbon emission in most province in China during the study period.

Chang et al. (2022) employed a non-linear autoregression distributed lag model to investigate the long-run interplay between the level of financial inclusion in China and renewable energy consumption. The outcome of the findings indicates that a corresponding driving positive effect between renewable investment in various province in China and the development of the financial sector through financial inclusion all through the study period from 2000 to 2022.

Abbasi et al. (2022) investigated the nexus between environmental sustainability and renewable energy production in China. Having made use of simulated auto regressive distributive lag techniques of data analysis, their findings depict that the utilization of fossil fuel in China continue to contribute to the negative impact of climate change through increase carbon dioxide emission during the study period between 1980 and 2018. The growth in China gross domestic product during the study period accounted for significant environmental degradation both in the long and short run. Contrary, only the utilization of clean energy significantly accounted for reduce carbon emission in both short and long run. The causality result depicts a dual causality running from both end between energy resources utilization in China and carbon reduction.

Saqib (2022) did made use of both augmented mean group and the common correlated effects mean group technique of estimation to establish the long-run causal linkage between non-renewable energy, financial development, carbon footprint and economic growth sixty-three emerging developing countries between 1990 and 2020. His findings reveal that all variables were cointegrated in the long-run and the utilization of non-renewable energy contributed to increasing carbon footprint in the respective sampled countries while the financial development and increasing use of green energy led to the growth of the respective sampled economy.

Ali et al. (2021) investigated the role of the utilization of combustible and waste energy in the of the thirteen European countries for a period of 1990-2019 using both granger causality test and Johansen cointegration methodology. They discovered a long-run positive and significant cointegration between the consumption of combustible and waste energy and growth in the gross domestic product as well as a bi-directional causality which led to the reduction in carbon emission during the study period. They advocated for the increase in the use of combustible and waste energy from biomass-based and waste source by the top highly developed European countries because of the existence of appropriate technology to reduce pollution.

Usman et al. (2021) utilized the augmented mean group (AMG) technique of estimation to explore the extent to which financial inclusion, renewable and non-renewable energy consumption

drives economic growth and reducing ecological footprint in the top fifteen countries that contributed most to carbon emission during the study period of 1990-2017. The findings from their analysis indicate that there exists a bidirectional connection between economic growth, utilization of renewable energy and financial inclusion.

Khan et al. (2020) employ the structural equation model to explore the efficiency of the use of renewable energy in logistic towards environmental sustainability and economic growth in Southeast Asia. The result of their finding indicates that government expenditure in the health sector will be reduce when renewable energy sources are utilized leading to greater environmental performance and subsequent growth in the economy of the Southeast Asia member country.

Shahbaz et al. (2020) utilized both the fixed and fully modified ordinary least square estimation techniques to explore the growth in the economy of countries having high attractive index for renewable energy between the period of 1990 and 2018. The outcome indicates that there was a long-run causal effect between the investment in renewable energy and growth in more than half of the country during the study period and more effort by all stakeholders must be tailored towards renewable energy investment which will reduce carbon emission.

Li and Li (2020) similarly employ the of the spatial Durbin model to explore the long run relationship that exist between energy investment in 30 provinces in China and the level of economic growth witnessed between 2001 and 2016 as well as the significant reduction in their respective carbon emission. The outcome of their findings reveals that the increase in carbon emission in the sampled province and cities was as result of the growth in the respective economy due to increasing investment in the energy sector.

Raza et al. (2020) reported a positive long run contribution to the consumption of renewable energy consumption as a result of increased development in the financial sector leading to more economic growth within the study period of 1997-2007 using a smoot transition regression methodology. They advocated for stable legal, monetary and fiscal discipline towards the availability of green funding for renewable energy consumption.

In Africa, Acheampong et al. (2019) focus their research on forty-six countries in the sub-Sahara region. Their research objective was to find out usefulness of renewable energy and foreign direct investment in the fight against negative impact of carbon emission in Africa. Applying both the fixed and random effect technique of data analysis, the study findings depict that environmental deterioration was greatly reduced through the utilization of renewable energy and investment from foreign bodies in most of the countries under investigation during the study period of 1980-2015. Their findings also gave support for the environmental Kuznets curve theory while on the other hand, the relative increase in population and exposure of most Africa countries to international trades accounted for significant increase in carbon emission during their study period.

3. MATERIALS AND METHODS

The research employed the panel auto-regressive distributive lag estimation technique on the study data from 1990 to 2023 periods to estimate the impact of renewable energy financing on sustainability in Africa. This technique allows for data evaluation for correlation, co-integration, Unit root test, diagnostic test, and both the short-run and long-run causal-effect relationship among the variables utilised to achieve the study objectives.

3.1. Data Source

For the purpose of investigating the contribution of renewable energy financing towards sustainable development in Africa from 1990 to 2023, data was sourced from the world development indicators (WDI) through the World Bank data bank. The world development indicator as a source of data collection for this study is justified because it is a reliable platform that aggregates information about various phenomena and presents them in a precise and understandable manner for utilization by various stakeholders.

3.2. Sample Size

For the purpose of investigating the contribution of renewable energy financing towards sustainable development in Africa, the sample size is limited to Nigeria, South Africa, Kenya and Egypt representing the each of the biggest economy in each geographical block in Africa. From the data source. This time frame reflects the availability of the relevant variable connoting renewable energy investment and sustainable development in Africa. The above selected period also depicts major developmental stages in Africa and increase commitment to sustainability.

3.3. Measurement of Variables

This subsection shows the sources of data collected for each variable utilized in the analysis of this study (Table 1).

For the purpose of investigating the contribution of renewable energy financing towards sustainable development in Africa from 1990 to 2023, this study adopts a model derived from Asemota and Olokoyo (2022) and Ogundipe et al. (2018).

3.4. Economic Sustainability

$$CAMAD = f(REUI, FODIV, TROPE, INFL, EXCR) \tag{1}$$

Where: CAMAD is the capital market development
REUI is renewable energy utilisation,
FODIV is foreign direct investment,
TROPE is the openness of trade,
INF is the inflation rate, and

EXCR is the exchange rate to the United State dollar for each Africa countries during the study period.

The study model is expressed in its explicit form below

$$CAMAD_{it} = \alpha_0 + \alpha_1 REUI_{it} + \alpha_2 FODIV_{it} + \alpha_3 TROPE_{it} + \alpha_4 INFL_{it} + \alpha_5 EXCR_{it} + \varepsilon_t \tag{2}$$

3.5. Environmental Sustainability

$$CARBEM = f(REUI, FODIV, TROPE, INFL, EXCR) \tag{3}$$

Where: CARBEM is carbon emissions for the selected countries under investigation, while the explanatory variables remain same above.

The study model is expressed in its explicit form below

$$CARBEM_{it} = \alpha_0 + \alpha_1 REUI_{it} + \alpha_2 FODIV_{it} + \alpha_3 TROPE_{it} + \alpha_4 INFL_{it} + \alpha_5 EXCR_{it} + \varepsilon_t \tag{4}$$

3.6. Social Sustainability

$$HUCAD = f(REUI, FODIV, TROPE, INFL, EXCR) \tag{5}$$

Where: HUCAD is the Human capital development index for the selected African countries under investigation.

$$HUCAD_{it} = \alpha_0 + \alpha_1 REUI_{it} + \alpha_2 FODIV_{it} + \alpha_3 TROPE_{it} + \alpha_4 INFL_{it} + \alpha_5 EXCR_{it} + \varepsilon_t \tag{6}$$

Where α_0 is the intercept, $\alpha_1 - \alpha_6$ are the coefficients/estimators, and ε_t is the residual or error term.

Table 1: Measurement of variables

S. No.	Variables	Identifier	Variable type	Measurement/description
1	Capital market development	CAMAD	Dependent variable	Total market value of outstanding shares in the capital market of the sample African countries
2	Carbon emission	CABEM	Dependent variable	Percentage of carbon emitted in the respective sampled Africa countries
3	Human capital development	HUCAD	Dependent variable	Percentage index of human development per sampled country
7	Renewable energy utilisation	REUI	Independent variable	Percentage of total energy produced and consumed from renewable sources
8	Direct foreign investment	FODIV	Independent variable	The total inflow in cash and cash equivalent from external investor (local currency)
9	Openness of trade	TROPE	Independent variable	The flow of trade with other counties as a percentage to the gross domestic product
10	Inflation	INFL	Control variable	Prevalent rate of consistent surges in general prices of goods and services (percentage)
11	Exchange rate	EXCR	Control variable	Official exchange rate to the United States of America dollar (rate)

3.7. Data Presentation and Analysis

In this sub-section, the overall descriptive summary of data for the panel employed in this study is presented. This is to avoid the violation of major statistical assumptions in the analysis of data collected on the employed variables and presented.

Table 2 shows that FODIV and TROPE have positive correlations for all three cases of CAMAD, CARBEM and HUCAD, while all the correlation are shown to be weak. This implies that increases or decreases in FODIV and TROPE are expected to result in corresponding increases and decreases in CAMAD, CARBEM and HUCAD individually and respectively. REUI, INFL and EXCR is then shown in Table 2 to have weak negative correlations with CAMAD, CARBEM, and HUCAD respectively. This denotes that increases or decreases in REUI, INFL, and EXCR are expected to lead individually to decreases or increases in CAMAD, CARBEM, and HUCAD respectively. All explanatory variables as shown in Table 2 do not have strong positive or negative correlations with each other.

3.8. Unit Root Test

Using the decision criterion, REUI, FODIV, TROPE, and INFL are revealed in Table 3 to have no unit root at levels, I(0), as their probability values at levels are found to be <0.05 at 5% significance level under the ADF and the PP unit root tests. This indicates their stationarity without differencing, i.e., at levels, I(0). Table 3 further shows that CAMAD, CARBEM, HUCAD, and EXCR are only stationary after first differencing, I(1), where the probability values became <0.05 at 5% level of significance after taking the first difference. The conclusion is that the variables are stationary at the mix of I(0)s and I(1)s, thus encouraging the use of panel ARDL.

3.9. Panel ARDL Analysis

The panel autoregressive distributed lag (P-ARDL) is employed to analyse the relationship between renewable energy financing,

measured by renewable energy utilisation (REUI), foreign direct investment (FODIV), trade openness (TROPE), inflation rate (INFL), as well as exchange rate (EXCR), and sustainable development split into economic sustainability measured by capital market development (CAMAD), environmental sustainability measured by carbon emissions (CARBEM), and social sustainability measured by human capital development (HUCAD). The use of panel ARDL is justified by the findings of the unit root test in Table 3 where the variables have a mixed order of stationarity. The nature of the short run and long run relationship between identified variables are presented as follows:

Table 4 reveals that only the model on CAMAD can converge back to its long run equilibrium in the case of any disequilibrium as the P-value of the convergence term COINTEQ01 is shown to be significant at 10% significance level. The convergence to long run equilibrium is affirmed by the negative sign which the cointegration coefficient is shown to have at -0.256, implying that any distortion in the model will converge to its state of long run equilibrium at the speed of 25.6%. The negativity of the cointegration under the models for carbon emission and human capital development shows the capacity for the models to converge back to long run equilibrium state at 24.8% and 5.4% respectively. However, since the relationships are shown to be insignificant, such expectations cannot hold.

Table 4 further shows that most of the explanatory variables measuring renewable energy financing do not have significant impacts on the dependent variables in the short run; except for trade openness which is found to positively and significantly influence carbon emissions at 5% significance level such that increase in trade openness by 1 unit will lead to increases in carbon emissions by 3750.537 units in the short run. Also, inflation rate, in this simulation, is shown to have a positive and significant influence

Table 2: Correlation matrix

	CAMAD	CARBEM	HUCAD	REUI	FODIV	TROPE	INFL	EXCR
CAMAD	1							
CARBEM		1						
HUCAD			1					
REUI	-0.616	-0.574	-0.886	1				
FODIV	0.095	0.219	0.162	-0.205	1			
TROPE	0.499	0.007	0.394	-0.322	0.108	1		
INFL	-0.539	-0.367	-0.411	0.363	0.058	-0.121	1	
EXCR	-0.489	-0.201	-0.655	0.758	-0.179	-0.627	0.391	1

CAMAD, CARBEM and HUCAD are the three different explained variables employed in this study while the others are the employed independent variables. Source: Researcher's Computation

Table 3: Unit root analysis

Variables	Level		1 st difference		Results
	ADF	PP	ADF	PP	
CAMAD	15.445 (0.051)	13.629 (0.092)	49.567 (0.000)	68.916 (0.000)	I (1)
CARBEM	9.295 (0.318)	8.753 (0.364)	56.545 (0.000)	52.310 (0.000)	I (1)
HUCAD	7.285 (0.506)	4.951 (0.763)	20.505 (0.009)	32.498 (0.000)	I (1)
REUI	22.096 (0.005)	19.323 (0.003)	-	-	I (0)
FODIV	26.745 (0.001)	23.619 (0.001)	-	-	I (0)
TROPE	20.605 (0.008)	18.970 (0.015)	-	-	I (0)
INFL	35.825 (0.000)	27.194 (0.000)	-	-	I (0)
EXCR	0.327 (1.000)	0.351 (1.000)	33.476 (0.000)	32.151 (0.000)	I (1)

Source: Researcher's computation

on human capital development at 5% significance level in the short run. This implies that, in the short run, a unit increase in inflation rate would lead to an increase in human capital development by 0.084 units.

3.10. Long Run Analysis

Table 5 shows that while renewable energy utilisation is shown to have a negative impact on both capital market development and carbon emission, this impact is revealed to be statistically significant for carbon emission but statistically insignificant for capital market development in the long run. This is because the P-value of the relationship with capital market development is >0.1 at 10% significance level while the P-value for the relationship with carbon emission is <0.01 at 1% significance level. This

Table 4: Short run analysis

Variable	Dependent variable - CAMAD	Dependent variable - CARBEM	Dependent variable - HUCAD
COINTEQ01	-0.256* (-1.696) [0.097]	-0.248 (-1.574) [0.121]	-0.054 (-0.749) [0.458]
D (REUI)	7.846 (1.241) [0.222]	-6.746 (-1.337) [0.186]	
D (FODIV)	-1.707 (-0.745) [0.460]	0.222 (0.109) [0.914]	-0.150 (-0.418) [0.678]
D (TROPE)	-19897.49 (-1.136) [0.263]	3750.537** (2.305) [0.025]	-178.843 (-0.427) [0.671]
D (INFL)	2.951 (0.945) [0.350]	0.148 (1.089) [0.281]	0.084** (2.078) [0.044]
D (EXCR)	2.583 (0.669) [0.507]	-0.877 (-0.595) [0.554]	0.137 (1.485) [0.145]
C	14.285 (0.726) [0.472]	241.262 (1.253) [0.554]	7.283* (1.696) [0.097]

T-stats are in [] and probability values are in (). ***, **, * represent significance at 1%, 5%, and 10% respectively. Source: Researcher's computation

Table 5: Panel ARDL long run analysis

Variable	Dependent variable - CAMAD	Dependent variable - CARBEM	Dependent variable - HUCAD
REUI	-0.663 (0.141) [0.889]	-11.829*** (-5.204) [0.000]	
FODIV	-11.268* (1.906) [0.064]	-23.507*** (-3.571) [0.001]	-4.694*** (-2.745) [0.009]
TROPE	38705.40** (2.417) [0.020]	52129.53*** (6.633) [0.000]	1124.651 (0.575) [0.568]
INFL	-20.524** (-2.166) [0.036]	-2.064** (-1.818) [0.074]	-0.417 (-0.908) [0.369]
EXCR	1.094 (1.045) [0.302]	-0.035 (-0.891) [0.376]	1.164*** (4.034) [0.000]

T-stats are in [] and probability values are in (). ***, **, * represent significance at 1%, 5%, and 10% respectively. Source: Researcher's Computation

implies that increases in renewable energy utilisation by 1 unit will lead to decreases in carbon emissions by 11.829 units in the long run.

Foreign direct investment is shown, in Table 5, to have significant but negative impacts on capital market development, carbon emissions, and human capital development in the long run at the significance levels of 10%, 1% and 1% respectively. While the relationship with carbon emissions conforms with a priori expectations, the relationship with capital market development and human capital development do not. The result denotes that increases in foreign direct investment by 1 unit will lead to decreases in capital market development by 11.268 units, in carbon emissions by 23.507 units and in human capital development by 4.694 units in the long run.

Table 5 also shows the impacts of trade openness on the dependent variables in the long run, where trade openness is revealed to impact all three dependent variables positively. The impact of trade openness on human capital development is shown to be statistically insignificant at 10% significance level. The result thus denotes that a unit increase in trade openness will lead to increases in both capital market development and carbon emissions by 38705.40 units and 52129.53 units respectively in the long run. While the results on CAMAD conforms with a priori expectation, the results on CARBEM does not conform with expectations.

It is further shown in Table 5 that inflation rate has negative impacts on capital market development, carbon emission, and human capital development in the long run but the impact on human capital development is shown to be statistically insignificant as the P-value for this relationship is >0.1 at 10% level of significance. These results demonstrate that increases in the inflation rate will lead to a 20.524-unit decrease in capital market development and a 2.064-unit decrease in carbon emissions in the long run. Exchange rate in this simulation is shown in Table 5 to have statistically insignificant impacts on capital market development and carbon emission, while exerting a positive and significant influence on human capital development in the long run. The relationship is demonstrated to imply that a unit increase in exchange rate will lead to 1.164-unit increase in human capital development in the long run.

4. DISCUSSION OF FINDINGS

In the short run, insignificant relationships were found between renewable energy utilisation and economic sustainability as well as between renewable energy utilisation and environmental sustainability in the short run. This opposes the findings of Alamgir and Cheng (2023) who found a significant relationship in the short run. However, in the long run, the relationships are revealed to be both negative but statistically insignificant for economic sustainability but significant for environmental sustainability. This finding opposes the findings of Raza et al. (2020), Ali et al. (2021), Chang et al. (2022), as well as Dimnwobi et al. (2022) who all found significant and positive relationship between renewable energy utilisation and economic sustainability.

A negative relationship of renewable energy utilisation with carbon emissions denotes a positive relationship with environmental sustainability. This confirms the findings of Li and Li (2020), Ye and Rasoulinezhad (2023), Zhao et al. (2023), Bergougui (2024), as well as Shabani (2024), who all found a positive relationship between renewable energy production/efficiency and environmental sustainability development in the long run. This study's findings, however, opposes the findings of Ofori-Sasu et al. (2023) who found a positive relationship between renewable energy utilisation and carbon emissions in the long run and the findings of Khan et al. (2020) who found a negative relationship between renewable energy usage and environmental performance.

The findings of the study on the impact of foreign direct investment on sustainability, oppose the findings of Destek et al. (2023) who found an insignificant relationship between foreign direct investment and environmental sustainability but supports the findings of Xuan et al. (2024) found a positive relationship between FDI and environmental sustainability. The findings further support that of Alshubiri (2021), who found negative relations between FDI and economic sustainability. The findings on inflation rate for all simulations are supported by the findings of Alshubiri (2021) as well as Ye and Rasoulinezhad (2023), who found that inflation rate played a negative role in achieving sustainable development.

4.1. Implication of Findings

The substantial impact of renewable energy financing on carbon emissions follows worldwide expectations and highlights clean energy as a solution to environmental deterioration. This finding demonstrates that switching from fossil fuels to renewable sources of energy strongly benefits environmental sustainability goals. In relation to this study's findings is how solar and wind plants implemented by China and the Green Deal initiative of the EU have decreased carbon emissions across multiple time frames. Renewable energy deployment is shown to have minimal effects on capital market expansion which indicates that various economies do not view these investments as essential drivers of financial growth. The low utilisation of renewable energy can be said to have emanated from slow policy implementation and expensive project initiation costs and low investor trust in extended returns on investments.

The outcomes further show that foreign direct investment (FDI) acts detrimentally to capital market development alongside human capital development. However, in accordance with environmental expectations, carbon emissions decrease from FDI. While the effect on carbon emissions is in conformity with priori expectations, the found effects on components of economic sustainability and social sustainability do not conform with priori expectation since standard economic theory shows that FDI should foster both capital market expansion and human capital enhancement. The findings depict that FDI inflows tend to inadequately support productive sectors which advance financial markets through time due to possible reasons including profit transfers by foreign firms as well as weak connections between foreign and local players and foreign business dominance within domestic markets.

Human capital development declines because of FDI, suggests that investment flows mostly target industries which provide limited skill enhancement opportunities such as resource extraction operations with their low-skilled and temporary workforce. The Nigerian oil industry demonstrates how major foreign direct investment inflows fail to create substantial human capital advancement because the sector combines capital-intensive practises and prefers employing international employees.

Trade openness is shown to facilitate the creation of more carbon emissions that negatively impact the environment. The observed direct link between market openness and capital market development meets economic predictions because open economies welcome foreign investments while enabling multinational corporations to enter local markets and strengthening financial associations. The transformation of Singapore and South Korea into thriving capital markets demonstrates this relationship since their economies became more open to trade. The major increase of carbon emissions resulting from trade openness creates serious environmental concerns because it indicates more trade activity can trigger increased industrial operations and resource depletion and greater fossil fuel usage thus exacerbating environmental damage. Trade expansion in China and India has resulted in higher greenhouse gas emissions because both countries underwent manufacturing and industrialisation growth.

Lastly, human capital development remains largely unaffected by trade openness even though expanded trade creates financial and economic growth. This can be attributed to the fact that most economic agreements tend to target immediate monetary benefits instead of developing human capital resources thus leading to such results. Numerous African nations demonstrate this phenomenon through their commodity-based trading activities since they primarily export unprocessed materials which restrict both employment possibilities and skills development for their citizens.

5. CONCLUSION AND POLICY RECOMMENDATION

This study centres on analysing the contribution of renewable energy investment to sustainable development in Africa. This study employs renewable energy, foreign direct investment and trade openness as the explaining variables, and inflation rate and exchange rate as the control variables. The study thus employed the panel ARDL estimation technique to analyse this relationship, which provides the nature of the relationships. In the short run, insignificant relationships were found between renewable energy utilisation and economic sustainability as well as between renewable energy utilisation and environmental sustainability in the short run. However, in the long run, the relationships are revealed to be both negative but statistically insignificant for economic sustainability but significant for environmental sustainability. A negative relationship of renewable energy utilisation with carbon emissions denotes a positive relationship with environmental sustainability. The nature of impact of renewable energy financing on carbon emissions follows worldwide expectations and highlights

clean energy as a solution to environmental deterioration. Renewable energy deployment has minimal effects on capital market expansion which indicates that various economies do not view these investments as essential drivers of financial growth. Environmental expectations support the carbon emission decreases from FDI, but standard economic theory shows that FDI should foster both capital market expansion and human capital enhancement. Human capital development declines because FDI suggests that investment flows mostly target industries which provide limited skill enhancement opportunities such as resource extraction operations with their low-skilled and temporary workforce. The observed direct link between market openness and capital market development meets economic predictions because open economies welcome foreign investments while enabling multinational corporations to enter local markets and strengthening financial connections.

This study suggests that government should utilize both fiscal and monetary instrument to encourage renewable energy investment in Africa. This can be in the form of tax incentive and grant on green project that are executed in Africa. Foreign direct investment should be channelled to green project that promote skill enhancement and sustainable workforce. The use of tailored regulation to create a renewable energy market for local and foreign investor and at the same time creating an unfavourable environment for investment in fossil fuel in Africa.

Attaining economic, environmental and social sustainability in Africa through renewable energy financing was limited to four Africa countries (Nigeria, South Africa, Kenya and Egypt). Additional research opportunities exist to explore these subjects further because of the study's established boundaries. A deeper analysis of the effects renewable energy financing and sustainable development indicators can focus on sector-specific variability between health, transportation, agriculture and manufacturing sectors in future studies.

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