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Navigating the climate challenges in Africa: Exploring the synergy and threshold effects of renewable energy and foreign direct investment on climate risk

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ABSTRACT

Renewable energy is widely acknowledged as an essential response to climate change, which poses a severe threat to humanity and natural ecosystems. Drawing from the greenhouse theory of climate change and the pollution haven hypothesis, this study contributes to the literature by addressing three critical issues. First, we examine the effect of renewable energy on climate risk. Second, we explore the intervening role of foreign direct investment (FDI) on the renewable energy-climate risk nexus. Third, we determine the minimum threshold required for renewable energy to minimise climate risk. The analysis was based on 47 African countries and estimated using the generalised method of moments (GMM) and dynamic panel threshold regression techniques. The GMM technique is essential due to its ability to address endogeneity issues in the model. Also, the dynamic panel threshold technique is employed because it is built on the principles of GMM and provides an estimate of the threshold level and nonlinearities in the model. The empirical evidence presents a significant negative relationship, suggesting that renewable energy minimises the surge in climate risk in Africa. Second, the findings reveal that the weakening effect of renewable energy on climate risk is contingent on FDI. Third, the dynamic panel threshold results demonstrate that the minimum threshold required for renewable energy to reduce climate risk is 56%. Beyond this level, renewable energy presents a significant negative impact, implying that high renewable energy consumption lessens climate risk. Policy recommendations for boosting renewable energy consumption to alleviate climate risk have been provided.

1. Introduction

Renewable energy has attracted much attention as a means to reduce climate change in the 21st Century. It is one of the key factors enshrined in the Sustainable Development Goals (SDGs), which aims to end poverty, improve energy security, promote economic growth and ensure prosperity for all [47]. This shows the widespread understanding of the significance of switching to low-carbon and more sustainable energy systems. As highlighted in Goals 7 and 13 on clean energy and climate action, renewable energy is crucial to reduce greenhouse gas emissions and combat climate change. Thus, the risk of climate change can be significantly reduced by employing renewable energy sources. This is because utilising renewable energy encourages sustainable production practices compared to conventional energy sources. Cities and communities can use renewable energy to become more sustainable and climate change resistant. Also, renewable energy provides a less expensive and efficient way to replace fossil fuels, which are limited and have negative environmental impacts and health problems [33]. These problems arising from fossil fuels threaten human lives. As a result, governments and international organisations are transitioning to renewable energy sources such as solar, wind, hydropower, geothermal and bioenergy to reduce the risks associated with fossil fuels and climate change [11].

Rising temperatures, changed weather patterns, rising sea levels, and an increase in the frequency and severity of extreme weather events are all symptoms of climate change, a significant global issue which is mostly attributed to the release of greenhouse gases from the burning of fossil fuels [16]. In light of these facts, countries have begun to develop several efforts to prevent these catastrophes. To reduce these issues, governments have begun reconsidering their energy strategies and regulations. Different strategies have been implemented to partially or entirely reduce greenhouse gases and their consequences [13]. Hence,

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switching to renewable energy sources has become a topical issue across the globe.

In Africa, renewable energy has gained popularity in alleviating issues with access to energy, encouraging sustainable development, and lessening the effects of climate change. Africa has a lot of potential for developing renewable energy due to its abundance of renewable energy resources, including solar, wind, hydro, geothermal, and biomass [18]. However, Africa faces more climate change issues due to rising energy demand [41]. Dube and Horvey [60] posit that fossil fuels still dominate Africa's energy mix, and the continent is moving more slowly toward sustainable energy use than other regions. This has increased the amount of greenhouse gases and carbon emissions released into the atmosphere, thereby worsening climate change-related issues. As a result, many African nations are at risk of climate change and are contending with problems like floods, drought, and other severe weather conditions that impact human health, water availability, and food security. Hence, increasing renewable energy is vital to address these pertinent issues. Therefore, it is not surprising that there is a heated discussion about reducing the harmful effects of climate change, which is mostly driven by conventional energy sources [17]. For this reason, adopting green or low-carbon energy sources that can supply energy for all is necessary for Africa to achieve a sustainable environment. Thus, renewable energy can help reduce greenhouse gas emissions and climate risk and promote climate resilience building. Hence, having access to clean and contemporary energy sources is a development objective established in the continent's economic development agenda. In light of this context, this study aims to explore the impact of renewable energyon climate risk in Africa through linear and nonlinear analysis. Further, the study examines whether foreign direct investment (FDI) fosters renewable energy use in reducing climate risk.

Despite the importance of renewable energy in addressing climate change, few empirical studies have sought to address this issue. For instance, scholars have explored the impact of globalisation and renewable energy on carbon emissions in Sub-Saharan Africa [1], vulnerabilities of renewable energy projection [7], renewable energy, governance, democracy and greenhouse gas emissions [2,39], renewable energy, nuclear energy and environmental pollution [38,31], renewable energy and environmental quality [4]. Ibrahim et al. [15] also analysed the heterogeneous impact of climate change and structural transformation on environmental pollution in Africa and found that renewable energy minimises the rise in carbon emissions. Another strand in the literature examined the role of FDI on environmental quality [38,28]. However, as far as we know, there is still a void in the literature regarding the impact of renewable energy on climate risk, particularly in Africa, which motivates this study. Climate risk tells how much weather-related loss occurrences, such as storms, heat waves, and floods, have impacted various nations and regions [9]. This is an essential factor because it goes beyond the amount of carbon dioxide and gas emissions released into the atmosphere by assessing its climate-related and associated vulnerabilities [19]. Hence, countries can determine the level of vulnerability and exposure to catastrophic occurrences, which serve as signals to be ready for any severe events. In order to make informed decisions, develop investment strategies, and create laws and regulations to address the problems posed by climate change, individuals, organisations, legislators, and financial institutions need to comprehend climate risk. Societies must endeavour to increase resilience, minimise vulnerabilities, and ensure sustainable development in the face of a changing climate by identifying and managing climate risk. To address this gap, this study empirically asks three questions. First, what is the impact of renewable energy on climate risk? Second, at what threshold level does renewable energy minimise climate risk? Third, does FDI moderate the relationship between renewable energy and climate risk?

Exploring the moderating influence of FDI is crucial because developing and deploying renewable energy infrastructure requires enormous investments. Thus, the development of the renewable energy sectors globally depends on mobilising the requisite financial resources, technological transfer, and knowledge sharing [46]. Also, FDI can help accelerate renewable energy consumption because it promotes knowledge and technology exchange and aids the transfer of these innovations from developed to developing economies, enabling them to access the most recent renewable energy solutions and technology [41]. Hence, we argue that the effect of renewable energy consumption on climate risk in Africa is contingent on FDI. In other words, this study indicates that the presence of FDI propels renewable energy consumption in reducing climate risk. Additionally, empirical contributions on the direct effect of renewable energy have been greatly examined [29,13,33]. However, previous studies have not explored the minimum threshold level essential for renewable energy to significantly reduce climate risk. This study seeks to address these gaps in the literature by examining forty-seven (47) African countries. The chosen context is essential given that, in 2022, over 600 million people in Africa live without electricity, as reported by the International Energy Agency (IEA) [50]. Additionally, Africa scored less than 40 out of 100 on the climate resilience index, implying that African countries are less resilient to climate change [51], making adopting renewable energy sources imperative.

In addressing these crucial gaps in the literature, this paper advances knowledge and policy discourse on renewable energy and climate risk, which align with the SDGs. First, this study expands our understanding of how renewable energy consumption affects climate risk in Africa. By highlighting this, we discover whether renewable energy reduces climate risk. Second, we examine whether FDI moderates the impact of renewable energy on climate risk. By examining this, the study informs African governments and international investors about the critical role of FDI towards achieving sustainable development. Third, this study advances knowledge by revealing the level of renewable energy required to reduce climate risk in Africa. In our opinion, this contributes to policymaking by helping governments and key stakeholders know the right amount of resources needed to be channelled into renewable energy sources to reduce climate risk. The rest of the paper is structured as follows. Section 2 discusses the theoretical and empirical literature on renewable energy, FDI, climate change and climate risk. Section 3 explains the data, methodology and empirical strategies. Section 4 analyses and discusses the empirical findings, and Section 5 provides a conclusion and policy recommendations.

2. Literature

2.1. Theoretical underpinnings between renewable energy, FDI and climate risk

Climate risk is a term used to describe the possible adverse effects and outcomes linked to climate change [9]. The expected changes in the climate system predicted by the greenhouse theory could outpace previous variations in the natural climate cycle as greenhouse gas concentrations rise. The theoretical link between renewable energy, FDI and climate risk is anchored on various scientific theories. Prominent amongst these include the greenhouse theory of climate change, the theory of decarbonisation and the pollution haven hypothesis (PHH). Understanding the greenhouse theory of climate change is essential to comprehending how climate change occurs. The greenhouse effect was first pointed out by Jean-Baptiste Fourier [10], who explained that human activities could modify climate change. Carbon dioxide, methane, and nitrous oxide are examples of gases that contribute to global warming and climate risk. Further, the combustion of fossil fuels and deforestation, in particular, has boosted greenhouse gas concentrations, strengthening the greenhouse effect and causing global warming. Due to these human activities, the atmospheric concentrations of various radiatively active gases have been rising [36]. The warming of the surface-troposphere system and cooling of the stratosphere, according to the greenhouse theory of climate change, will bring the climate system back into balance. This natural occurrence is necessary to keep the earth's average temperature at a level that supports life. This will reduce the risks associated with climate change and advance a more sustainable and resilient future by cutting greenhouse gas emissions, implementing sustainable practices, and boosting resilience.

From the above narrative, we see that the adverse impact of climate change can be reduced by switching to renewable energy sources, cutting greenhouse gas emissions and putting sustainable behaviours into practice. This aligns with the theory of decarbonisation, which explains the process of reducing or eliminating carbon dioxide (CO_2) emissions from many industries, particularly the energy industry. This theory further highlights that renewable energy is essential to reduce carbon emissions as a substitute for fossil fuel-based energy sources, which are a major source of greenhouse gas emissions [2,27]. Wesseling et al. [48] posit that an expedited transition to profound decarbonisation is necessary to reach 2050 emission targets. One of the factors that can help to transition to deep decarbonisation is foreign direct investment. This is emphasised by the PHH, which investigates the impact of FDI inflows on environmental quality [34]. Sarkodie et al. [41] anticipate that the influx of FDI will positively impact the environment by increasing total investment. They argue that FDI facilitates the transfer of technology and management techniques, resulting in lower carbon emissions and renewable energy transition in developing countries. This is consistent with Delevingne et al.'s [8] assertion that decarbonisation is accomplished by increasing the share of low-carbon energy sources, particularly renewables, and correspondingly reducing the usage of fossil fuels, thereby addressing climate risk.

Notably, these theoretical viewpoints imply that the level of renewable energy needed to reduce climate risk in Africa is contingent on FDI. Despite the theoretical relationship between renewable energy, FDI and climate risk, empirical research that offers evidence-based suggestions to help with policy design is difficult to come by. In this light, this study contributes to our understanding of this area because, to the best of our knowledge, there are no empirical contributions in the literature in this direction.

2.2. Empirical literature on the linkage between renewable energy, FDI and climate change

Energy security and sustainability are at risk due to rising consumption and resource use associated with fossil fuels and greenhouse gas emissions. As a result, the global policy agenda has been restructured to guarantee and integrate environmental sustainability through avenues like renewable energy [55]. Renewable energy consumption is essential to combat climate change and reduce climate risk. Renewable energy sources provide a sustainable alternative to fossil fuels, which increase greenhouse gas emissions because they primarily rely on naturally replenishable resources, including sunshine, wind, water, and geothermal heat. Nazir et al. [31] explain that the world requires immediate and practical efforts to safeguard the climate for a brighter tomorrow to reduce or limit environmental insecurity and climate risk concerns. Hence, finding new energy alternatives is imperative, as it reduces total reliance on fossil fuels. Renewable energy can support climate risk management by minimising vulnerabilities to climate-related dangers. For instance, increasing renewable energy consumption in water-stressed economies can lead to significant water savings. This argument is supported by Lee et al. [26], who suggest an important relationship between renewable energy technology, climate risk and energy poverty. Hence, countries should consider the critical role of climate risk and its association with renewable energy.

Another essential reason for renewable energy consumption is that they are frequently spread and decentralised, which increases their resistance to disruptions caused by climate change. Contrary to centralised fossil fuel infrastructure, renewable energy technology such as solar panels and wind turbines can be installed in various places, lowering reliance on weak transmission networks and reducing the effects of catastrophic weather occurrences. In examining the critical role of renewable energy, most studies focus on its impact on climate change without explicitly investigating how it reduces extreme weather-related events. For instance, Riti et al.'s [38] research revealed that while traditional energy sources undermine environmental sustainability, renewable energy, financial development, and population growth benefit environmental quality. This aligns with Beken et al.'s [54] findings that the increase in renewable energy consumption reduces carbon emissions. This is further confirmed by Bekun [53], who found an inverse relationship between carbon emissions and renewable energy, explaining that, amidst economic growth trajectory, renewable energy acts as a remedy for sustainable development. Luderer et al. [30] explored the role of renewable energy in climate stabilisation. They found that almost all energy modelling forums (EMF27) mitigation scenarios depict a significant increase in renewable energy production, particularly a significant expansion of wind and solar energy use. In many scenarios, renewables are the most important long-term mitigation option for power supply.

De Lucena et al. [7] investigated the vulnerability of renewable energy to climate change in Brazil. The study's most significant finding is the growing energy vulnerability of Brazil's poorest regions to global climate change. Sarkodie and Adams [40] found a negative relationship between renewable energy and fossil fuels in South Africa. This supports Hu et al.'s [14] finding that increasing the fraction of renewable energy consumption lowers emissions based on an empirical investigation of 25 developing economies. They suggest that developing nations should encourage trade in commercial services and the proportion of renewable energy consumption for low-carbon economic growth. Similarly, from the ASEAN perspective, Liu et al. [29] show that non-renewable energy positively correlates with carbon emissions and predicts an inverse relationship between renewable energy and carbon emissions. Their findings further suggest short-term granger causal relationships between non-renewable energy, emissions, and agriculture, as well as between economic growth and agriculture and directly between agricultural and renewable energy. The existence of granger causalities between emissions, renewable energy, and non-renewable energy is indicated by long-run causalities. Quito et al. [55] sought to determine whether investments and using renewable energy are pushing economies toward higher energy efficiency and sustainable economic growth. They noted that renewable energy improves energy efficiency and has spillover effects on neighbouring countries, suggesting the need for greener and more sustainable energy use. More so, research indicates that using renewable energy sources can help lower energy intensity and promote the use of cleaner fuels [56]. Governments can also encourage energy security through it [57].

An essential strategy for combating climate change and managing climate-related risk is the increase of renewable energy sources. However, the level of renewable energy consumption in Africa is still small compared to other continents. A report by Statista indicates that the amount of energy generated from renewable energy sources in Africa as of 2020 was 9%. The current low levels of renewable energy consumption in Africa can be linked to several things, such as poor infrastructure, legislation and financial access. Dube and Horvey [60] assert that the small share of clean energy in the energy mix results from the poor investment in renewable energy in Africa. Given that renewable energy initiatives inherently entail substantial expenses. It requires a large investment [58]. They further argue that underdeveloped financial systems may impede the promotion of renewable energy businesses even in situations where demand is high. Hence, to ensure the development and growth of renewable energy, there is a need for high financial investment such as FDI. Wei et al. [61] concurs with this assertion that FDI is a crucial factor in expanding sustainable energy use. This is because capital, technology, and knowledge can be brought via FDI influx to help the development of renewable energy sectors in many nations. Knutsson and Flores [22] add that FDI reduces climate change because renewable energy projects require significant investment. Hence, FDI assists in mobilising the necessary financial resources. It provides access to cash, which helps create, build, and operate renewable energy infrastructure. Lin et al. [59] observed a cointegration link between finance and renewable energy. Their findings showed that finance has a beneficial effect on renewable energy.

Also, FDI has the potential to boost economic development and open job possibilities in the host nation. This is because renewable energy projects require a sizable construction, operation, and maintenance workforce. Hence, FDI provides an avenue that creates jobs and may have positive economic effects. An empirical study on FDI and renewable energy by Sarkodie et al. [41] reveals the role of FDI in renewable energy consumption. Their findings show that FDI enhances renewable energy consumption in addressing climate change issues. This is consistent with Jiang et al. [20], who conclude that FDI could be a very efficient avenue for transferring technology to underdeveloped nations. Similarly, Neequaye and Oladi [32] and Opoku et al. [35] argue that FDI inflows improve environmental quality due to their significant impact on renewable energy resources. Wei et al. [61] found similar results, suggesting that FDI boost renewable energy production. On the contrary, Salahuddin et al. [39] suggest that renewable energy and FDI increase carbon emissions in Kuwait in the short and long run. This situation is possible when FDI is not driven by renewable energy consumption. Hence, they recommend high investment into renewable energy resources to achieve the global climate change target.

Overall, the literature reveals the importance of renewable energy towards climate change. However, potential areas remain for further investigation, particularly in Africa, where renewable energy consumption is growing. The literature indicates that most studies explore the impact of renewable energy on carbon and greenhouse gas emissions without explicitly assessing its effects on climate risk. This is essential to determine the potential influence of renewable energy consumption on the negative consequences and effects arising from climate change and its associated risks. This follows the recommendation by Solaun and Cerdá [44], who suggest the use of different variables of climate change to assess the overall impact of renewable energy on the environment. In addition, previous studies have considered the direct, long-run and short-run relationships without determining the threshold level at which renewable energy consumption is needed to mitigate climate risk. The study further considers the moderating influence of FDI on the relationship between renewable energy and climate risk.

3. Methodology

3.1. Data

The study employs annual data for forty-seven (47) African countries between 2006 and 2019. The period chosen for this study was informed solely by data availability for the variables. For instance, data for climate risk is glaringly absent for countries such as Eritrea, Eswatini, Libya, Sao Tome, Somalia, and South Sudan. The description of the variables is presented in Table 1. Variables such as renewable energy consumption and FDI were drawn from the World Development Indicators (WDI) database of the World Bank. All the control variables (political stability, government effectiveness and regulatory quality) were captured from the World Governance Indicators (WGI) database, except GDP per capita, which was sourced from WDI.

For the outcome variable, climate risk, the study adopted the global climate risk index published by Germanwatch. The index is one of the most trustworthy data sources on the effects of extreme weather occurrences and associated socioeconomic data and is based on data from MunichRe NatCatSERVICE [9]. The index analyses the impact of climate-related extreme weather occurrences on different countries and areas. The indicators for creating this index are based on the number of fatalities and economic losses within a period (i.e., fatalities, fatalities per 100,000 inhabitants, absolute losses (in million US$ PPP and losses per unit GDP in%). Renewable energy consumption, which is the independent variable, assesses the percentage of renewable energy in total final energy consumption [44]. The moderating variable, FDI, tells the number of international investments and economic globalisation of a country. For the control variables, we employ GDP per capita, political stability, government effectiveness and regulatory quality to capture the effects of economic performance and the quality of institutions of a country [41]. This is important because better institutions promote climate governance, ensuring better structures and policies for climate risk mitigation.

Table 1
Description of Variables.

Variables	Descriptions	Symbol	Source
Climate Risk	Climate Risk Index	CRI	Germanwatch
Renewable Energy Consumption	Renewable energy consumption (% of total final energy consumption)	RENW	WDI
Foreign Direct Investment	Foreign direct investment, net inflows (% of GDP)	FDI	WDI
Gross Domestic Product	GDP per capita growth (annual%)	GDP	WDI
Political Stability	Political Stability and Absence of Violence/ Terrorism: Estimate	Political	WGI
Government Effectiveness	Government Effectiveness: Estimate	Gov_Effect	WGI
Regulatory Quality	Regulatory Quality: Estimate	Reg_Qual	WGI

3.2. Empirical strategies

There are two sections to the empirical analysis for this study. First, the study examines the interaction between renewable energy and foreign direct investment on climate risk. Second, the study examines the nonlinear relationship between renewable energy and climate risk. Due to this, the study uses two estimating techniques: the dynamic panel threshold and the generalised method of moments (GMM).

3.2.1. The interaction between renewable energy and FDI on climate risk

The dynamic system GMM estimator developed by Arellano and Bond [3] is used in this study to evaluate the impact of renewable energy on climate risk. The literature reveals that the GMM model outweighs the performance of the static model because it can control for measurement errors and omitted variables. It also controls endogeneity problems by utilising time-series variations in the data and controlling for unobserved country-specific effects. It is important to note that adding lags of the dependant variables in our model will likely create endogeneity issues. For instance, the lagged dependant variable depends on the lagged error term, a function of the country-specific fixed effects. The study employed this method to build a model where the dependant variable depends on its lag and a vector of independent variable observations. The second endogeneity concern relates to the potential bi-causal relationship between renewable energy and climate risk. Given this, we resort to the dynamic system GMM estimator. A two-step GMM is also preferred over a one-step GMM. The two-step system GMM estimator, as opposed to the one-step GMM estimator, has the advantage of better addressing potential instrument proliferation and overfitting. It is also more effective due to its asymptotically consistent and trustworthy results [5]. As a result, our model is expressed as:

$$CRI_{it} = \beta_1 CRI_{it-1} + \beta_2 RENW_{it} + \beta_3 FDI_{it} + \beta_4 (RENW * FDI)_{it} + \beta_5 GDP_{it} + \beta_6 Political_{it} + \beta_7 Reg\_Qual_{it} + \beta_7 Gov\_Effect_{it} + \mu_i + \partial_t + \varepsilon_{it} \quad (1)$$

where CRI represents climate risk index; CRI_{it-1} represents the one-period lag of the dependant variable; RENW represents renewable energy consumption; FDI represents foreign direct investment; GDP represents gross domestic product per capita; Political represents political stability; Reg_Qual represents regulatory quality; Gov_Effect represents government effectiveness; β represents the parameters to be estimated; μ_i represents the unobserved country-specific fixed effects; ∂_t represent the time fixed-effect and ε_{it} is the idiosyncratic error term.

In order to capture the net effect of the interaction between renewable energy and FDI, the study adheres to the guidelines outlined in [6]. This includes testing for the joint significance of the constitutive and interaction terms. The net effect was calculated by taking the first derivative of the constitutive and interactive terms with respect to renewable energy in Eq. (1). As a result, the following details were included in our model:

$$\textbf{Net Effects}: \frac{\partial CRI}{\partial RENW} = \beta_2 + \beta_4 \mathrm{FDI_{it}} = 0 \quad (2)$$

Hence, the level of renewable energy interacted by foreign direct investment is examined by the summation of the coefficients ($\beta_2 + \beta_4$) and the test of the significance of the joint effects.

It is important to consider that the accuracy of the GMM technique in producing robust results is determined by its post-estimation tests, which are taken into account. To evaluate the instrument's validity, we apply Hansen's test of over-identification [52]. The Hansen test is based on the null hypothesis that no correlation exists between the detected instruments and the residuals. As a result, the suitability of the instruments and, consequently, the reliability of our estimations depend on the failure to reject the null hypothesis. If the null hypothesis is rejected, the instruments are not robust since the limitations brought about by relying on the instruments are invalid. The validity of our estimates is further assessed using the post-estimation tests for (i) the absence of second-order serial correlation in the residuals, (ii) the significance of the interaction terms, and (iii) the number of instruments is less than the number of groups.

3.2.2. Dynamic panel threshold regression

To provide policymakers with information on the threshold required and sufficient for renewable energy consumption to reduce climate risk, we employ the dynamic panel threshold model suggested by Seo and Shin [42] and Seo et al. [43], who extends the threshold model developed by Hansen [12] and Kremer et al. [23], to analyse the nonlinear relationship. The dynamic panel threshold technique is built on GMM principles. It addresses the inherent endogeneity and simultaneity that cannot be avoided in the relationship between renewable energy and climate risk. Furthermore, the conventional dynamic panel model only captures the average effects in the regression model but fails to disclose the impact of structural breaks in the model. The dynamic panel threshold technique overcomes this limitation by splitting the sample into two and reports the estimated threshold level of the model. Additionally, it gives us the potential impact of the threshold variable when it falls below/above the threshold and also presents the confidence interval of the threshold value [52]. The general model is specified in Eq. (2) as:

$$y_{it} = x_{it}^{'}\beta + \left(1,\ x_{it}^{'}\right)\delta 1\{q_{it} > \gamma\} + \mu_i + \varepsilon_{it}\ i = 1, \ldots, n;\ t = 1, \ldots T \quad (3)$$

Where y_{it} is the dependant variable for country i at period t; q_{it} represents the threshold variable and x_{it} includes the lagged dependant variable. T is assumed to be fixed, whereas n is assumed to grow indefinitely. The fixed effect μ_i is removed using the first difference process, and then the unknown parameters are estimated using GMM. Thus, $\theta = (\beta', \delta', \gamma')$. Based on the specified general model by Seo et al. [43], the specific model for the study is stated as

$$\mathrm{CRI_{it}} = \begin{cases} \alpha_1 \mathrm{CRI_{it-1}} + \theta_{11}\mathrm{RENW_{it}} + \theta_{12}\mathrm{Controls_{it}} + \mu_i + \varepsilon_{it}\ if\ \mathrm{q_{it}} \le \gamma \\ \alpha_1 \mathrm{CRI_{it-1}} + \theta_{21}\mathrm{RENW_{it}} + \theta_{22}\mathrm{Controls_{it}} + \mu_i + \varepsilon_{it}\ if\ \mathrm{q_{it}} > \gamma \end{cases} \quad (4)$$

For $i = 1, \ldots, n;\ t = 1, \ldots T$ where q_{it} is the threshold variable which is renewable energy consumption, and γ is the threshold parameter in the model, which splits the coefficients into two regimes.

4. Analysis and discussion

4.1. Summary statistics

The results in Table 2 provide a descriptive overview of the variables and their correlations. The mean for the climate risk index (CRI) for the period under review is 78.46. The results further show great variation in CRI in Africa, with a standard deviation of 29.88, and the minimum and maximum values are 2.670 and 152.580, respectively. For renewable energy consumption, Africa recorded an average value of 60.184, which implies an ongoing shift from fossil fuels to renewable energy in Africa. FDI records an average value of 4.666, while GDP records a mean of 1.746. The result shows a great deal of variation in GDP, having a minimum value of −36.778 and a maximum value of 19.939 over the study period. The data shows that political stability, regulatory quality and government effectiveness have negative mean values over the period, indicating poor institutional quality in Africa. Hence, there is a need for African countries to make significant progress toward improving their institutional landscape.

The correlation analysis shows that the independent variables are not strongly associated. As a result, multicollinearity is absent, and the variables are deemed suitable for use in the regression model. Improvements in some of the institutional quality indicators will have a favourable impact on other institutional quality measures because of the high correlation between some of these variables. Therefore, institutional complementarities might be advantageous for Africa. The negative correlation between climate risk and renewable energy supports the argument in Fig. 1.

4.2. Overview of renewable energy and climate risk in Africa

In this aspect of the analysis, we employ graphical analysis to show the developments of renewable energy and climate risk in Africa over the study period. It is important to note that the purpose of the analysis is based on the region's progress toward renewable energy consumption over the study period. Fig. 1 shows a priori relationship between renewable energy consumption and climate risk. The results show renewable energy and climate risk are strongly related in Africa. The scatterplot line further indicates an inverse relationship between these variables. Hence, increasing renewable energy consumption will reduce climate risk. This finding offers more justification for looking into this relationship and seeing if the observed pattern holds empirically.

The average country-level usage of renewable energy is shown in Fig. 2. Information gleaned from Fig. 2 suggests that the Democratic Republic of Congo has the highest average value (96.13) of renewable energy consumption in Africa. This is followed by the Central African Republic (92.75). We further see a springing up of renewable energy consumption in countries such as Ethiopia (92.30), Uganda (92.24), Burundi (91.29) and Rwanda (87.74). Algeria (0.20) remains the country with the minimum renewable energy consumption. In addition, we see Seychelles (1.10), Egypt (5.60), Equatorial Guinea (5.65) and South Africa (10.63) belonging to the bottom five. This is because fossil fuels, thermal energy and hydropower stations mostly dominate the energy mix of these countries.

The average share of climate risk across countries in Africa is presented in Fig. 3. This reveals that Equatorial Guinea (108.00) and Seychelles (104.43) have the minimum climate risk in Africa over the period. Contrarily, Madagascar (32.45), Mozambique (38.53), Niger (43.81) and South Africa (45.85) were the countries with the highest climate risk in Africa over the period under review. This could be attributed to several reasons. For instance, in March 2017, Madagascar (7) had its worst hurricane in almost a decade, causing floods and landslides. Cyclone Ava struck Madagascar in January 2018, making landfall on the island's eastern side, where towns were inundated and structures destroyed [25,7]. The high level of climate risk in Mozambique can be attributed to the intense tropical Cyclone Idai,

Table 2
Descriptive Statistics and Correlation Matrix.

Variable	CRI	RENW	FDI	GDP	Political	Reg_Qual	Gov_Effect
Obs	658	658	658	658	658	658	658
Mean	78.468	60.184	4.666	1.746	−0.557	−0.642	−0.712
Std. Dev.	29.887	30.207	8.516	4.234	0.991	0.741	0.732
Min	2.670	0.060	−11.197	−36.778	−3.281	−2.548	−2.349
Max	152.580	97.330	103.337	19.939	1.598	1.429	1.505
Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)
(1) CRI	1.000						
(2) RENW	−0.202	1.000					
(3) FDI	0.045	0.026	1.000				
(4) GDP	−0.046	0.035	0.057	1.000			
(5) Political	−0.003	−0.041	0.015	0.059	1.000		
(6) Reg_Qual	−0.102	0.084	0.048	0.104	0.623	1.000	
(7) Gov_Effect	−0.066	−0.032	0.019	0.100	0.677	0.890	1.000

Note: CRI represent climate risk index; RENW represents renewable energy consumption; FDI represents foreign direct investment; GDP represent gross domestic product per capita; Political represents political stability; Reg_Qual represents regulatory quality; Gov_Effect represents Government effectiveness. Source: Stata.

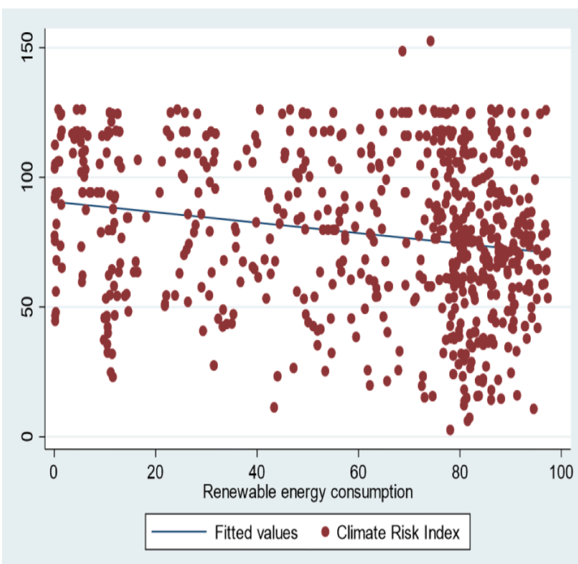

Fig. 1. Scatter Plots of Renewable Energy Consumption and Climate Risk Index.

which hit Mozambique and its neighbouring countries in March 2019, causing catastrophic damage and humanitarian crises [45]. Niger experienced massive flooding brought on by Niger's heavy rains, causing damage to homes, numerous crops, and hydro-agricultural developments [37,7]. South Africa and Kenya also experienced massive rainfalls and landslides over the period.

4.3. *Regression analysis on renewable energy, foreign direct investment and climate risk*

The study begins the presentation of the main findings by examining the conditional and unconditional effects of renewable energy on climate risk, as shown in Table 3. As earlier described in our methodology section, the GMM estimation technique was employed for analysis. All the estimated models are valid when compared to the validity criteria used to evaluate GMM models as described in sub-Section 3.2.1. This is supported by the AR(2)'s insignificant values, which suggest no second-order serial correlation. The Hansen test is statistically insignificant across the models, confirming the validity of the instruments. The lagged dependant variable's (climate risk) coefficient value is statistically significant, demonstrating the dynamic nature of the regression model.

The analysis begins by explaining the bivariate results on the effect of renewable energy and FDI on climate risk, as presented in models (1) and (3). Models (2) and (4) include control variables for robustness and to determine the persistency of the relationship. The results indicate a negative relationship between renewable energy and climate risk. This confirms the relationship in the correlation matrix in Table 2. This relationship was statistically significant in model (2) in light of the control variables. The empirical evidence indicates renewable energy is essential for decreasing the effects of climate change and creating a more resilient future because it helps with the transition away from fossil fuels, the reduction of greenhouse gas emissions, and the promotion of sustainable development. This supports the greenhouse theory of climate change, which posits that the adverse effect of climate risk can be reduced by switching to renewable energy sources [27]. This is not without empirical support. The negative relationship is highlighted by Sarkodie et al. [41], who explain that an increase in renewable energy consumption promotes environmental sustainability. Li et al. [56] affirm this, suggesting that using renewable energy sources can help lower energy intensity and promote the use of cleaner fuels. As a result, there is a need for a paradigm shift from greenhouse gases and carbon emissions to renewable energy use to ensure a green and sustainable environment [53].

The results in Models (3) and (4) present that FDI is positively related to climate risk. The coefficient value of FDI suggests that an increase in foreign investment exacerbates climate risk. Hence, FDI may fall short of spurring environmental sustainability in Africa. This is possible when FDI is channelled into using fossil fuels and hydropower [28]. In Africa, the level of FDI into renewable energy is low as most FDI is directed towards natural resource extraction, leading to environmental degradation [21]. This is affirmed by Dube and Horvey [60], who assert that the small share of clean energy in the energy mix results from poor investment in renewable energy in Africa. This aligns with Opoku and Boachie's [34] findings that FDI may cause an increase in carbon emissions due to their positive results. They explain that FDI in Africa is a significant contributor to carbon and greenhouse gas emissions due to their enormous investment in industrialisation, which relies heavily on fossil fuels. Therefore, it is crucial to comprehend the environmental implications of private investment and determine the best response.

Models (5) to (7) explore the interactive effects of renewable energy and FDI on climate risk. We first explored the impact of renewable energy and FDI on climate risk in model (5), while model (6) includes the control variables. Finally, model (7) adds the interaction terms to determine the intervening role of FDI on the renewable energy-climate risk nexus. The results show a significant negative impact of the interaction between renewable energy and FDI on climate risk. This conforms with the pollution haven hypothesis and implies that when FDI is channelled into renewable energy consumption, it reduces climate risk.

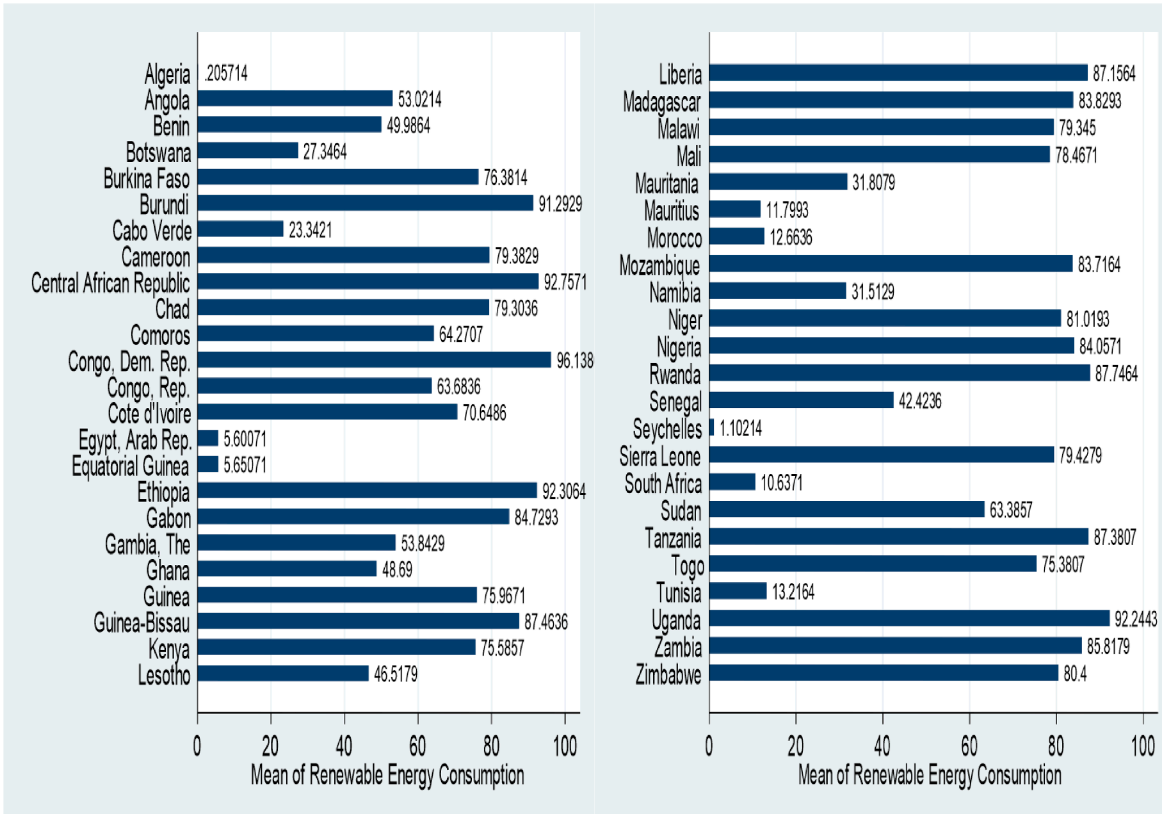

Fig. 2. Average Renewable Energy Consumption in Selected Countries in Africa, 2006–2019.

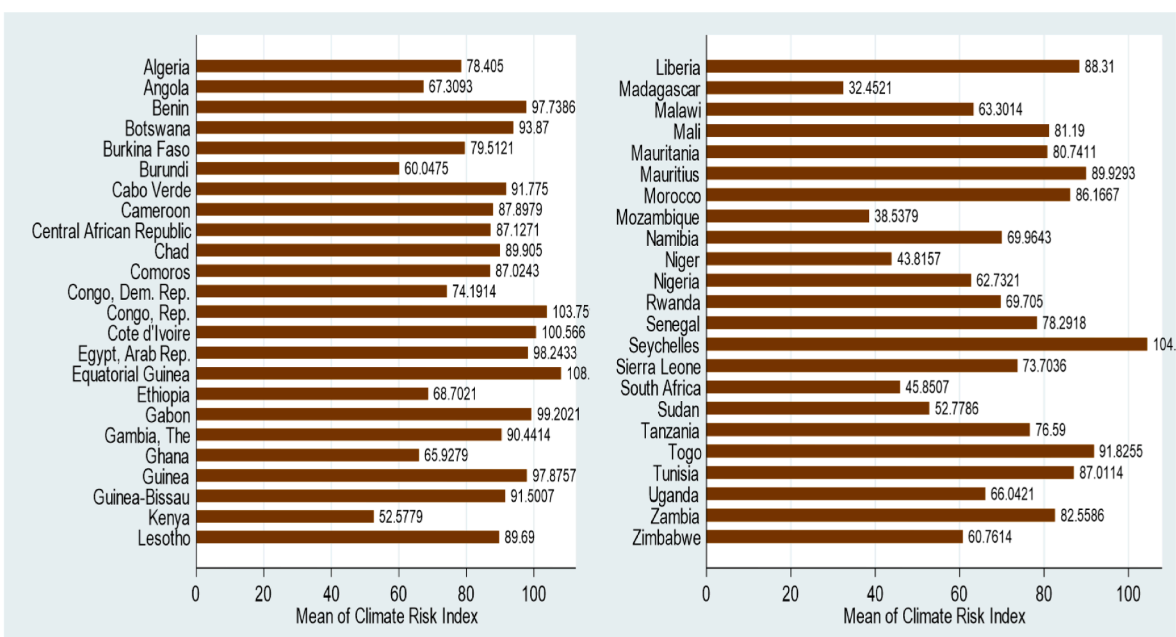

Fig. 3. Average Climate Risk Index in Selected Countries in Africa, 2006–2019.

This is consistent with Knutsson and Flores's [22] argument that the engagement of FDI in renewable energy consumption will help decrease climate risk. Wei et al. [61] support this assertion by indicating that FDI is crucial in expanding sustainable energy use. Hence, African countries must provide clear-cut policies and long-term strategies and build the infrastructure required to integrate renewable energy sources, which will encourage foreign investment in renewable energy. That said, we proceed by computing the net effects, which also provides an equally compelling finding, holding all other factors constant. It is worth noting that the net effect was computed using Eq. (2). We compute the net effect as:

Table 3
Results for Renewable Energy, Foreign Direct Investment and Climate Risk Index.

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Lag of CRI	1.074*	0.111**	0.123**	0.109**	0.118**	0.106*	0.107**
	(0.573)	(0.052)	(0.048)	(0.052)	(0.048)	(0.053)	(0.053)
RENW	−0.002	−0.191**			−0.184**	−0.186**	−0.100
	(0.096)	(0.075)			(0.070)	(0.073)	(0.082)
FDI			0.323	0.350*	0.328*	0.344*	1.406***
			(0.201)	(0.208)	(0.177)	(0.182)	(0.289)
RENW*FDI							−0.015***
							(0.004)
GDP		−0.036		−0.069		0.031*	0.005*
		(0.033)		(0.031)		(0.013)	(0.307)
Political		0.607		0.777		0.592	1.432
		(0.679)		(0.745)		(0.554)	(0.709)
Reg_Qual		−1.254*		−5.842		−1.895*	−3.352*
		(0.933)		(1.109)		(1.232)	(1.989)
Gov_Effect		−0.959		3.350		−0.342	−0.023*
		(0.080)		(0.900)		(1.040)	(0.723)
Net Effects							−0.0169***
Country and Time Dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Prob>F	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Observations	611	610	611	610	611	610	610
No. of Countries	47	47	47	47	47	47	47
No. of Instrument	9	13	9	10	13	14	15
AR(1)	0.034	0.000	0.000	0.000	0.000	0.000	0.000
AR(2)	0.112	0.077	0.107	0.115	0.098	0.102	0.112
Sargan	0.737	0.196	0.319	0.244	0.327	0.243	0.242
Hansen	0.746	0.262	0.436	0.371	0.449	0.359	0.331

Note: Robust standard errors in parentheses;.
*** $p < 0.01$,.
** $p < 0.05$,.
* $p < 0.1$; CRI represents climate risk index; RENW represents renewable energy consumption; FDI represents foreign direct investment; GDP represent gross domestic product per capita; Political represents political stability; Reg_Qual represents regulatory quality; Gov_Effect represents Government effectiveness. Source: Stata.

$$\frac{\partial CRI}{\partial RENW} = -0.100 + (-0.015 \times FDI)$$

$$\frac{\partial CRI}{\partial RENW} = -0.100 + (-0.015 \times 4.666) = -0.169$$

The analysis yields a significant negative net effect, as shown in Model (7). The findings carry significant implications for policy development and climate risk mitigation. It highlights that increased renewable energy consumption in conjunction with FDI is likely to reduce climate risk. Given that renewable energy initiatives inherently entail substantial expenses. It requires large investments [58]. The net effect offers policymakers a valuable opportunity to significantly advance their efforts to foster and mitigate climate risk when the right resources are channelled into it [34]. One such way is by re-directing FDI flows into renewable energy consumption. By so doing, it could lessen the potential impact of greenhouse gas emissions, thereby reducing climate risk. This could manifest in several ways, especially when FDI is directed towards solar, wind, biomass, and other renewable energy resources. Foreign investors play a crucial role in shaping global economic activities, and their commitment to directing substantial resources toward renewable energy resources can have a transformative impact on climate change mitigation.

The control variables shed light on additional factors influencing climate risk and offer valuable insights for policymakers to consider in their strategic decision-making. First, the research reveals mixed findings for the impact of GDP, but notably, models (6) and (7) demonstrate a significant positive relationship. This significant positive relationship aligns with the argument by Xu and Lin [49] that economic growth often leads to increased carbon emissions due to its association with industrialisation and high energy consumption. Thus, policymakers must be cautious about the potential trade-offs between economic growth and climate change mitigation efforts. It is necessary to adopt measures that promote sustainable economic growth while actively addressing the environmental impact of increased economic activity.

Further, government effectiveness presents a negative relationship with climate risk. This is obvious since good governance helps direct social systems to avoid, reduce, or adjust to the dangers caused by climate change [41]. Political stability also presents a positive relationship, highlighting the critical role of a stable political environment in fostering successful climate change adaptation and mitigation strategies. The positive results show that in a region with high political unrest, this may compromise efforts to adapt to and mitigate the effects of climate change. Political instability may result in unstable policies, poor governance, and insufficient funding for addressing climate-related concerns. Given this finding, policymakers should prioritise efforts to promote political stability, social cohesion, and inclusivity to create an environment that enables climate action. Stable political systems are more likely to support consistent, long-term climate policies, provide sound governance practices, and successfully allocate enough resources to address climate concerns [40]. The study revealed a negative relationship for regulatory quality and was statistically significant. This underscores the importance of robust regulatory frameworks and supervision in mitigating climate risks through the implementation of policies and guidance related to climate issues [41]. Effective regulations are critical in guiding government agencies, organisations, and industries toward incorporating climate risk considerations into their operational activities, helping reduce society's and economies' vulnerability to climate risks.

4.4. *Threshold results for renewable energy and climate risk*

The empirical results from the threshold analysis in this section provide essential insights for policymakers, helping to understand the minimum threshold of renewable energy adoption required to mitigate climate risk in Africa. The findings from the dynamic panel threshold estimation reveal a significant nonlinear relationship. Table 4 provides evidence that the bootstrap p-value (0.000) for linearity rejects the null

Table 4
Threshold Analysis between Renewable Energy and Climate Risk Index.

Variables	Lower Regime	Upper Regime
Lag of CRI	−0.153	0.624***
	(0.146)	(0.226)
FDI	1.668	−4.490**
	(1.112)	(1.884)
GDP	3.662***	−2.378***
	(1.182)	(0.642)
Political	−6.853	2.129
	(14.45)	(2.585)
Reg_Qual	−3.459*	−4.888*
	(2.035)	(3.324)
Gov_Effect	−6.005	9.255
	(5.448)	(8.257)
RENW	1.267	−8.372**
	(2.506)	(3.733)
Postestimation Tests		
Threshold Point (r)	55.68**	
	(26.95)	
95% Confidence Interval	[1.734 – 107.532]	
Linearity (p-value)	0.000	
Observations	47	

Note: Robust standard errors in parentheses;.
*** $p < 0.01$,.
** $p < 0.05$,.
* $p < 0.1$; CRI represent climate risk index; RENW represents renewable energy consumption; FDI represents foreign direct investment; GDP represent gross domestic product per capita; Political represents political stability; Reg_Qual represents regulatory quality; Gov_Effect represents Government effectiveness. Source: Stata.

hypothesis that there is no threshold effect in all models, proving the nonlinear relationship between renewable energy and climate risk. As a result, the various factors are divided into upper regime/lower regime when the threshold value is greater than/less than or equal to the threshold indicator.

The associated findings, based on the threshold regression, are novel and revealing. First, the study estimates a significant threshold of 55.68% for renewable energy consumption in Africa. This suggests that reaching a minimum threshold of 56% renewable energy consumption is essential to reduce climate risk effectively. Below this threshold, the impact of renewable energy is positive and insignificant, indicating that it is insufficient to mitigate climate risks at low renewable energy consumption. However, beyond the threshold level, the relationship becomes negatively significant. This demonstrates that higher adoption of renewable energy leads to cleaner energy with low carbon dioxide and greenhouse gas emissions [24]. This aligns with Bekun et al.'s [54] assertion that increasing renewable energy consumption reduces carbon emissions. This change contributes to a decrease in the atmospheric buildup of heat-trapping gases, hence minimising the risks connected with global warming. This is a necessary and effective cause to reduce climate challenges. Bekun [53] adds that renewable energy is environmentally friendly, which will likely lead to growth in economies and a green environment.

Similarly, the analysis reveals that FDI flows into Africa have a positive impact when it falls below the threshold but a negative and significant impact above the threshold value. This highlights the importance of increasing FDI inflows to Africa, mostly directed towards clean energy investments, as it can effectively contribute to climate change mitigation in the region [41]. This finding is especially illuminating, indicating that African governments should scale up investment in renewable energy by drawing international investors to encourage clean energy investment. This supports Lin et al.'s [59] finding that green finance significantly affects renewable energy use, reducing climate risk. Therefore, Quito et al. [55] suggest the need for more investment in green energy to improve energy efficiency and ensure a more sustainable environment.

Regarding GDP, the results indicate a positive relationship below the threshold and a negative relationship above the threshold level. This is in harmony with the environmental Kuznet curve hypothesis, suggesting an inverted U-shaped relationship between economic growth and environmental degradation [24]. The Kuznet curve hypothesis suggests that environmental degradation increases at the early stages of economic growth. However, environmental quality emerges once economic growth reaches a certain point, particularly involving higher economic growth [32,34]. This implies that at the initial stages of economic growth, high climate risk is inevitable, thereby harming the environment, but this is likely to decline when GDP grows above a certain level. Regulatory quality is also negative in the upper threshold, while political stability and government effectiveness fail to present significant values. Policymakers should be mindful of this relationship and implement measures to decouple economic growth from environmental degradation, emphasising sustainable and green economic development.

4.5. Robustness analysis

In checking for the robustness of the results, access to clean energy was used as another proxy for renewable energy consumption. This is mostly used as another measurement for renewable energy in the literature [22]. As revealed in Table 5, our baseline results confirm a negative relationship between clean energy and climate risk. FDI also shows a positive but insignificant relationship. The study finds a negative relationship between the coupling effect of clean energy and FDI on climate risk. This is further supported by the net effect of −0.053, which was computed as follows:

$$\frac{\partial CRI}{\partial RENW} = -0.048 + (-0.001\ \times FDI)$$

$$\frac{\partial CRI}{\partial RENW} = -0.048 + (-0.001\ \times\ 4.666) = -0.053$$

Even though the net effect is insignificant, the result is intuitively appealing, affirming the argument that adopting modern forms of energy will promote sustainability by reducing climate change issues [14]. Regarding the threshold regression, the coefficient estimates in Table 6 confirm an inverse relationship at a higher threshold level and a positive relationship below the threshold. The results suggest that strategic investment and policies geared towards renewable energy will likely trigger a sustainable environment. Hence, FDI can be leveraged to promote green energy in Africa.

5. Conclusion and policy recommendations

This study significantly contributes to the discourse on climate change in Africa by examining the relationships between renewable energy, FDI and climate risk using data from 2006 to 2019. The research aligns with the SDG agenda, which seeks a more sustainable energy system, particularly Goals 7 and 13, which support a switch from greenhouse gas to renewable energy, as well as the African Union Agenda 2063 on sustainable development. We do so by first examining the direct impact of renewable energy on climate risk. Second, we explore the coupling effect of renewable energy and FDI on climate risk. Additionally, we determine the threshold level at which renewable energy declines climate risk. The analysis was based on the two-step system GMM and the dynamic panel threshold estimation techniques.

In accordance with the literature, we find that renewable energy consumption plays a crucial role in promoting environmental sustainability by reducing climate risk, as evidenced by its significant negative impact on climate risk. Therefore, African countries should plan the growth of renewable energy consumption while considering climate risk. Further, the study shows that the interaction between renewable energy and FDI is negatively related to climate risk. This indicates that the effect of renewable energy on climate risk mitigation is remarkable

Table 5
Results for Clean Energy, Foreign Direct Investment and Climate Risk Index.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Lag of CRI	1.515*	1.504*	1.488*	1.468*	1.482*	1.469*	1.489*
	(0.785)	(0.749)	(0.789)	(0.760)	(0.804)	(0.769)	(0.762)
Clean Energy	−0.055	−0.052*			−0.051	−0.048	−0.048
	(0.106)	(0.100)			(0.110)	(0.103)	(0.069)
FDI			0.042	0.037	0.036	0.031	0.036
			(0.146)	(0.152)	(0.161)	(0.165)	(0.127)
Clean Energy*FDI							−0.001*
							(0.009)
GDP		0.063		0.071		0.064	0.061
		(0.285)		(0.276)		(0.277)	(0.285)
Political		1.163		1.067		1.167	1.140
		(1.415)		(1.387)		(1.361)	(1.486)
Reg_Qual		2.208		2.446		2.029	2.132
		(4.256)		(4.954)		(4.350)	(4.617)
Gov_Effect		−1.364		−1.667		−1.285	−1.303*
		(3.730)		(3.872)		(3.623)	(3.670)
Net Effects							−0.053
Observations	611	610	611	610	611	610	610
Country and Time Dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes
No. of Countries	47	47	47	47	47	47	47
No. of Instrument	9	13	9	10	13	14	15
AR(1)	0.051	0.043	0.045	0.050	0.049	0.021	0.014
AR(2)	0.150	0.146	0.158	0.159	0.164	0.161	0.154
Sargan	0.732	0.753	0.735	0.752	0.729	0.750	0.754
Hansen	0.689	0.700	0.695	0.701	0.689	0.699	0.704

Note: Robust standard errors in parentheses; *** $p < 0.01$, ** $p < 0.05$,.
* $p < 0.1$; RENW represents renewable energy consumption; FDI represents foreign direct investment; GDP represent gross domestic product per capita; Political represents political stability; Reg_Qual represents regulatory quality; Gov_Effect represents Government effectiveness. Source: Stata.

Table 6
Threshold Analysis between Clean Energy and Climate Risk Index.

Variables	Lower Regime	Upper Regime
Lag of CRI	0.039	0.152***
	(0.084)	(0.031)
FDI	1.603	−1.630*
	(1.597)	(0.980)
GDP	1.190	−1.330
	(0.981)	(1.574)
Political	2.523	−4.238*
	(2.715)	(2.684)
Reg_Qual	−1.865	5.286
	(4.013)	(4.258)
Gov_Effect	−2.438*	−2.826**
	(1.445)	(1.087)
Clean Energy	1.398	−1.112*
	(1.127)	(0.688)
Postestimation Test		
Threshold point (r)	52.93**	
	(24.55)	
95% Confidence Interval	[2.432 – 97.557]	
Linearity (p-values)	0.000	
Observations	47	

Note: Robust standard errors in parentheses;.
*** $p < 0.01$.
** $p < 0.05$.
* $p < 0.1$; RENW represents renewable energy consumption; FDI represents foreign direct investment; GDP represent gross domestic product per capita; Political represents political stability; Reg_Qual represents regulatory quality; Gov_Effect represents Government effectiveness. Source: Stata.

in the presence of substantial foreign investment. This implies that when FDI is directed towards renewable energy resources, it can foster climate change mitigation in the region. The results unveil a threshold level of 56% for renewable energy consumption, emphasising that reaching and surpassing this threshold is crucial to effectively reducing climate risk in Africa. At their disaggregated regimes, we find that renewable energy shows a significant negative relationship above the threshold level, indicating that heavy reliance on renewable energy in Africa will help weaken climate risk. This does not only result in climate risk reduction but also a more sustainable clean energy use. Therefore, countries with relatively high climate risk should prioritise renewable energy consumption. The study also yields support to the environmental Kuznet curve hypothesis, implying an inverted U-shaped relationship between GDP per capita and climate risk.

The findings offer some policy recommendations. The study found that a threshold effect exists between renewable energy and climate risk, which suggests that when renewable energy consumption is low, climate risk will be high and vice versa. Therefore, policymakers are encouraged to channel substantial resources to boost renewable energy consumption to alleviate climate risk. Policymakers should also strike a balance between FDI and sustainable growth in the renewable energy sector by encouraging responsible investment practices that contribute to cleaner and more sustainable energy. It is essential that FDI aligns with sustainable and environmentally friendly practices. This can be enhanced when international bodies such as the World Bank, the United Nations, the African Development Bank and foreign investors provide the technical and financial support to complement government efforts in improving renewable energy consumption in Africa, especially in areas with high climate risk. To incentivise foreign investors towards renewable energy consumption, African countries should prioritise environmentally sustainable financial inflows and investments, particularly in green technologies. The various sectors of African countries, such as the manufacturing and industrial sectors, should adopt environmentally sustainable practices to reduce carbon emissions into the atmosphere. Moreover, there is a need to introduce carbon taxes to reduce carbon emissions in African countries. Also, policymakers need to offer incentives such as tax advantages and other financial support to organisations using renewable energy to encourage sustainable practices. Further, governments should develop appropriate systems to address issues such as political instability, corruption, and government ineffectiveness and enhance the regulatory environment, as good governance plays a crucial role in achieving sustainable development goals. By creating a conducive regulatory environment and implementing effective policies, policymakers can attract foreign investors and foster the pursuit of renewable energy consumption on the continent. Such policies should not be limited to foreign investors but also target local investors and households.

While the study provides valuable insights into the issue of renewable energy and climate risk, it acknowledges some limitations, which gives room for further studies. The study only focused on the interaction and threshold effects of renewable energy and FDI on climate risk. Hence, scholars could extend this line of enquiry by exploring the bi-causality between this relationship while considering the impact of different sources of capital flows' on the relationship between renewable energy consumption and climate risk. The study failed to consider the various sources of FDI and which sectors receive these investments, which could be examined in future studies. Again, the study did not investigate the effect of this relationship for countries at different income levels. As a result, future studies could disaggregate the analysis into the type of income groups (thus, low-, middle- and high-income countries). There are different types of climate risks; hence, scholars could consider other proxies when considering related topics. Also, it will be worthwhile to consider country-specific analysis of the renewable energy-climate risk nexus. These endeavours will deepen our understanding and inform more targeted policy interventions tailored to the respective countries to address climate challenges.

CRediT authorship contribution statement

Sylvester Senyo Horvey: Writing – original draft, Validation, Formal analysis, Data curation, Conceptualization. **Jones Odei-Mensah:** Writing – review & editing, Validation, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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