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Institutional quality and renewable energy capital flows in Africa

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Abstract

This paper investigates the linear and nonlinear relationship between institutional quality and renewable energy capital flows across 20 African countries between 2002 and 2017. The empirical evidence is based on the generalised method of moments estimation technique. The findings suggest that institutional quality has a significant and propelling effect on renewable energy capital flows, implying that strong institutions induce investments in renewable energy in Africa. From an extended analytical exercise, the study further shows a nonlinear inverted U-shaped relationship between institutional quality and energy capital flows. This indicates that the enhancing effect of institutional quality on energy capital flows is achieved at a certain threshold level. In the extreme case, the impact of institutional quality on energy capital flows diminishes. The study recommends that African countries initiate reforms to tame any adverse effect of institutional quality on renewable energy investments in its extreme case. Thus, African countries should develop strong institutions and reinforce their regulatory frameworks because strong institutions can improve societal welfare by reducing political, social and economic unpredictability while boosting trust and investment in renewable energy.

Keywords Institutional quality, Renewable energy capital flows, Linearity, Nonlinearity, Africa

JEL Classification E02, O13, Q42

Introduction

Access to clean and modern energy sources by all Africans is a development goal enshrined in the economic development agenda of the continent. This is driven by the critical role that energy holds in economic development, making energy infrastructure a precondition for economic growth and a key pillar of good governance and sustainable development [38]. In addition, good governance and a strong institutional environment encourage renewable energy investment [12]. However, fossil fuels still dominate the energy mix in Africa, and the transition to clean energy sources is still slow compared to other regions [54]. Africa has one of the lowest and most rapidly fluctuating renewable energy investments. In 2019, renewable energy investments declined significantly even in countries with top investment recipients in previous years, particularly in Kenya, where investment commitments declined by 45% [21]. This has contributed to the smaller share of renewable energy in the energy mix of most countries in Africa. As a result, most African countries are exploring ways to attract renewable energy investments. However, attracting renewable energy investments into the region is mired by numerous challenges, and a majority hinge on governance and institutional quality [14]. Institutional quality is important to promoting investments because it enhances the formation of trade agreements, protects property rights and minimises transaction costs [27, 53]. Poor institutions have adverse effects on investments and sectoral growth,

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particularly in the energy sector [37], because it reduces the efficiency and contribution of the sector to economic growth [11, 30].

Regrettably, despite the growing literature on how institutional quality affects economic growth [25, 48], income inequality [3], foreign direct investment [7, 9, 33, 35] and taxation [55], studies have failed to examine the relationship between institutional quality and renewable energy capital flows. To put the identified shortcoming into greater perspective, Abeka et al. [1] examined the impact of economic and political institutions on renewable energy without considering the importance of institutional quality. Saadaoui and Chtourou [52] also explored the relationship between institutional quality and renewable energy consumption in Tunisia. However, they failed to explore how institutional quality affects renewable energy capital flows, leaving a lacuna in the literature. Therefore, it is against this background that the study explores the role of institutional quality in attracting renewable energy capital flows into Africa.

This study is important to the economic development agenda of Africa in various ways. Firstly, most governments worldwide have shifted their emphasis from fossil fuels to clean and modern electricity sources. Therefore, it is imperative that developing countries initiate institutional reforms that will remove barriers in the investment environment, attract renewable energy investment and improve access to clean and modern energy sources [5]. Secondly, renewable energy technologies are changing the energy mix of most African countries, therefore requiring the region to develop policies that will promote their integration into the African energy market. Thirdly, the region also requires significant investment that is targeted at building reliable power systems, and these investments can only be attained through building efficient and robust institutions [29].

To address the gap, the study adopts the generalised methods of moments (GMM) estimation technique for analysis. GMM is used due to its ability to control endogeneity problems [6]. The index of economic freedom is employed as a proxy for institutional quality because it includes a wider range of institutional quality characteristics. This is one of the robust indexes, capturing different dimensions of the institutional quality framework. To the best of our knowledge, this is the first study to explore the relationship between institutional quality and renewable energy investments in Africa. We further provide evidence on possible nonlinear effects between institutional quality and renewable energy capital flows. The results from the regression analysis indicate a significant positive relationship between institutional quality and renewable energy finance, indicating that institutional quality enhances renewable energy capital flows. Furthermore, the study finds evidence to support the argument that a nonlinear inverted U-shaped relationship exists between institutional quality and renewable energy capital flows.

The rest of the paper is structured into the following sections: "Literature review" section provides a brief overview of institutional quality and renewable energy finance while discussing the empirical literature on institutional quality and renewable energy finance. "Data and methodology" section discusses the data, methodology and empirical strategies. "Results and discussion" section analyses and discusses the empirical result, and "Conclusion and recommendations" section provides a conclusion and policy implications.

Literature review

Brief Overview of Institutional Quality and Renewable Energy Finance in Africa

Fossil fuels still dominate the energy mix in Africa, and the transition to clean energy sources is still slow compared to other regions [54]. The low investment in renewable energy contributes to the insignificance of clean energy in the energy mix. However, a slight progress has been made towards clean energy since 2000 and 2017. According to African Energy Commission (AFREC), the proportion of coal as a source of electricity is declining, while the renewables (geothermal, solar, etc.) are slightly increasing (AU 2019). Figure 1 illustrates the changes made from 2000 to 2017.

Furthermore, the volatility of oil prices and growing energy demand in most African countries are accelerating the pace of the transition to renewable energy sources, particularly in oil-dependent countries (da Silva et al. 2018). Therefore, the region needs significant capital flows to support the transition to renewable energy and achieve universal access to energy. A total maximum investment of $1.3 trillion is forecasted to be required to ensure the region has universal energy access by 2030 [23]. This places significant pressure on the region to upscale investments into the energy sector and improves attractiveness to private investors.

Energy financing in Africa

According to the International Renewable Energy Agency (IRENA) [32], renewable energy investment has been increasing rapidly over the years; only 2% was channelled to Africa, even though the region has huge potential and a need for increasing access to electricity. Between 2010 and 2020, Africa received about USD 55 billion. In North Africa, Egypt and Morocco received USD 8.2 billion and USD 9.5 billion, respectively. West Africa received USD 4

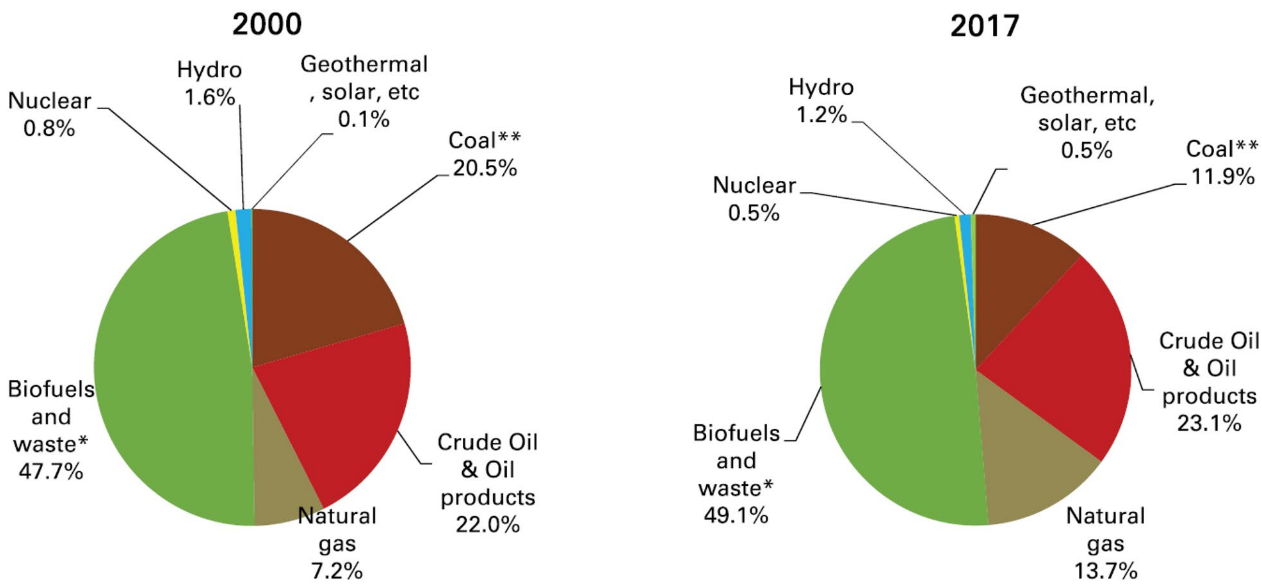

Fig. 1 Electricity sources in Africa 2000–2017 (AU, 2019)

billion over the period 2010–2020, and Nigeria accounted for a significant portion of the total investments, followed by Senegal, Mauritania, Ghana, Sierra Leone and Burkina Faso.

East Africa received USD 9.7 billion between 2010 and 2020, and Kenya accounted for 58%, followed by Ethiopia at 17%. Central Africa received the least investment (USD 1.3 billion) of all regions, and Cameroon, the Democratic Republic of the Congo and Gabon received most of the investments. Southern Africa received 40% (USD 22.4 billion) of total renewable energy investment in Africa. South Africa was the main recipient (85%) through the Renewable Energy Independent Power Producer Procurement (REIPP) programme. Public finance dominates the energy capital flows into the region. Since 2010, Africa has attracted the largest (37%) public finance [31]. However, there are significant differences in the capital across the region [11]. South Africa, Angola and Egypt were awarded about half of the public finance between 2014 and 2016 [40].

Private capital sources are minimal, ranging between debt and equity financing [31]. Total private capital in the renewable energy sector is prevalent in South Africa. South Africa's Renewable Energy Independent Power Producer (REIPP) programme has attracted significant private capital [28]. According to a survey by the United Nations Environment Programme Finance Initiative (UNEP FI) [56], renewable energy finance in Africa is impeded by challenges ranging from competition for capital with fossil fuels, weak regulatory frameworks and macroeconomic risks. Renewable energy technologies face stiff competition from fossil fuels in the allocation of capital resources because governments continue to subsidise fossil fuels, therefore making renewables short term or costly to implement, particularly at a large scale. Further, the legal and regulatory environment of the electricity sector in most countries creates constraints in Africa in deploying renewable energy technologies. The energy sector is predominantly controlled by the state, with a monopoly market structure that creates barriers to entry to third parties and private independent power producers UNEP [56].

Hafner et al. [23] also reveal that some countries in Africa have regulatory frameworks that do not promote the enforcement of contracts (power purchase agreements). These challenges have a dire effect on energy projects compared to other infrastructure projects because their realisation is linked to country-specific risks (regulatory, political, macroeconomic). Another set of challenges to financing renewable energy in Africa stems from the lack of an enabling framework that promotes the ease of doing business for renewable energy enterprises in a country [24]. In some countries, it still takes a long time to start, operate and close a business, particularly in the energy sector, because of the novel technologies that may require numerous licences and permits. As a result, such challenges raise the cost of debt and may negatively influence capital flows into the renewable energy sector [42].

The Quality of Institutions in Africa

Institutional development in Africa remains a huge concern in the bid to improve access to clean and modern sources of energy by all Africans. Low-quality institutions are at the core of the economic fragility of most African states, and one cannot rule out the effects of colonial history in the persistent state of institutional decay [13]. At independence, most African countries emerged with complex and illegitimate institutions, even worse than during colonisation, leading to systemic poverty across the continent [2].

The recent governance report by the Mo Ibrahim Foundation [47] also shows that Africa has been on a decade-long decline in institutional quality. Public perception of overall governance in Africa has deteriorated significantly since 2015, and only eight countries met all the governance categories. Nonetheless, significant improvements have been observed over the years in indicators measuring foundations for economic opportunity and human development, which are the key drivers of overall governance. Security, the rule of law, participation, and rights and inclusion also showed a downward trend in 2019. Therefore, it is evident that Africa needs to accelerate efforts towards improving the quality of institutions to attract capital flows into the renewable energy sector and improve access to clean and modern energy sources by all Africans.

Further, the Mo Ibrahim Foundation Governance Index shows that institutional quality declined in most African countries between 2019 and 2021 following the global COVID-19 pandemic. Mauritius continued to rank high in overall governance; however, the score was the lowest in over a decade. South Africa, Botswana, Ghana, Tanzania, Uganda and Zimbabwe made significant progress in developing foundations for economic opportunity. Algeria, Egypt, Kenya and Nigeria improved human development. However, there was a significant decline in security and the rule of law in most countries, such as South Africa, Mauritius, Ghana, Mozambique and Nigeria (Mo Ibrahim Foundation, 2021). The decline in security and the rule of law is a worrying trend because it can potentially affect the ability to attract capital flows for renewable energy projects.

Renewable energy finance–institutions nexus

Financial development is critical to the growth of the energy sector. It facilitates the efficient allocation of financial resources, information sharing and setting the rules for exchanging goods and services [49]. This argument is underpinned by the New Institutional Economics (NIE) theory which explains that institutions play a critical role in enforcing contracts, protecting private property rights and alleviating transaction costs in the exchange of goods and services [44]. Institutions represent the rules of the game in an economy and influence the efficiency of markets and reduce transaction costs of doing business [43]. Institutions also promote the formation of trade agreements amongst states by reducing information asymmetry during trade agreement bargaining [53]. Institutions also enhance the protection of property rights and minimise government interference through expropriation [27].

Empirical studies that examine the role of institutions in attracting renewable energy investments are few. Most studies focus on the role of institutions in attracting FDI [7, 9, 33, 35]. Asiedu and Freeman [8] investigated the effects of corruption on investment growth for transition countries in Latin America, the Caribbean and sub-Saharan Africa (SSA). Their results reveal that corruption has no significant impact on investment growth. Kurul [39] also introduces the nonlinear relationship between quality institutions and investments. They find that the effect is positive after institutional development exceeds a certain threshold [3, 36].

However, energy investments differ from other forms of foreign capital because of their high sunk costs, capital intensity, limited recourse and non-tradable nature. Therefore, institutional quality may influence them differently from other forms of capital. Previous studies analysed the significance of institutional quality, particularly political risk, in the oil sector. Asiedu and Lien [9] found that the oil sector continued to attract FDI and was highly profitable even when political risk was high. Busse [16] also argues that even the most repressive government regimes attract investments from multinational oil companies and conclude that institutional quality matters in FDI, targeting the manufacturing and services sector. Álvarez et al. [4] recently investigated the effect of quality institutions on sectoral trade. They find that quality institutions lead to growth in trade in the primary sector, particularly the energy sector, more than the benchmark. However, Uzar [57] explains that this relationship is only significant in the long run but not in the short run due to its insignificant results. Aziz and Mishra [10], therefore, narrate that countries endowed with energy resources need to develop the quality of their institutions to attract high investment into the sector.

Ragosa and Warren [50] examined factors influencing cross-border investment in the renewable energy sector in developing countries. Their findings are that international public finance, regulatory support and political stability drive investment into the renewable energy sector. However, the effects of the business environment were not statistically significant on renewable energy investment. This is consistent with Ren et al. [51], who reveals that sound institutional quality and a good governance environment attracts investors to renewable energy. Baumli and Jamasb [11], while examining the financial and non-financial barriers to renewable energy investment in Africa, found that factors related to energy market openness, effective renewable energy policies and government effectiveness drive capital flows into the renewable energy sector. On the contrary, Imam et al. [30], while investigating the effects of corruption on the electricity sector in SSA, found that corruption adversely affects reforms in electricity by reducing the sector's efficiency and contribution to economic growth.

However, these effects are reduced when independent regulatory institutions and privatisation are implemented. Junxia [34] posits that corruption in the energy sector is high in central Asia; nevertheless, it does not deter energy investments. Masini and Menichetti [44] surveyed a group of investors in Europe to determine the factors influencing the share of renewable energy investment in the energy portfolios. Their results show that institutional and behavioural factors significantly influence the share of renewable energy technologies in energy portfolios. Despite these arguments, Saadaoui and Chtourou [52] suggest no conclusive arguments on the role of institutional quality in renewable energy. They explain that countries with high levels of corruption and political instability weaken investment in renewable energy. This is because political instability disturbs changes in environmental conditions which affects renewable energy investments. This argument is supported by Ergun et al. [20], who indicated that the level of democracy does not impact renewable energy capital flows. Chen et al. [19] affirm this assertion by narrating that less democratic nations with fewer environmental policies become a "pollution haven", which can adversely affect productive investment into renewable energy.

Ren et al. [51] add that high corruption levels negatively influence renewable energy investments, particularly when it exceeds a certain threshold. This tends to increase the production cost of firms due to market failure and economic disorder, which therefore reduces the enthusiasm of international investors in renewable energy. Furthermore, Fredriksson and Svensson [22] state that high corruption and political instability destroy good environmental policies. When this happens, the demand for a quality environment is ignored because corruption weakens the strict observance of energy policies, which tends to negatively impact the environment, including investment into renewable energy. To overcome these adverse impacts, Ren et al. [51] suggest a sound institutional environment to incentivise investors to invest in renewable energy. Cadoret and Padovano [17] also establish that implementing a strong institutional environment and sound energy policies is essential to promote capital flows into renewable energy. Also, institutional reforms should precede energy policies to strengthen their impact on renewable energy capital flows.

In light of the above discussion, we find that scholars have greatly explored different aspects of renewable energy finance with specific emphasis on renewable energy consumption, energy efficiency and infrastructure, as well as other reforms in the energy sector. However, the evidence of the effects of the individual, institutional quality factors on renewable energy capital flows, to the best of our knowledge, remains incipient. Hence, this study provides further evidence of the role of institutional quality in attracting investments into the renewable energy sector in Africa, an area that has not been explored widely.

Data and methodology

To assess the nexus between institutional quality and capital flows in the energy sector, we employed a panel dataset of twenty (20) African countries (see Table 6) covering 2002–2017. The period chosen for this study was determined solely by the availability of data for the variables. The study used the index of economic freedom (EFI) published by the Heritage Foundation for institutional quality variables. The index contains four distinct aspects capturing different dimensions of the institutional quality framework. These include the rule of law, government size, regulatory efficiency and market openness, graded on a scale of 0 (poor institutional quality) to 100 (strong institutional quality). Within these four measures, there are 12 specific components. First, the rule of law measures the protection of property rights by a country's legal framework, judicial effectiveness and government integrity. Second, government size also measures the tax burden on personal, corporate and overall tax base as a percentage of gross domestic product (GDP), government spending and fiscal health, which relates to the country's debt burden and deficits.

Third, regulatory efficiency measures business freedom which relates to the constraints of starting and operating a business, labour freedom and monetary freedom, which relates to inflation stability. The fourth aspect relates to market openness which measures trade freedom pertaining to the ability to trade with other countries, investment freedom which relates to the ease of flow of investment capital and financial freedom. The study adopts this index because it is one of the widely used indexes for institutional quality. The index is already computed, thereby avoiding any biases in personal computations. It is also easily accessible and has many characteristics regarding institutional quality. The index components are weighted equally to ensure that there is no bias towards a single component [26].

The study used the International Renewable Energy Agency (IRENA) database of renewable energy finance projects to assess data for renewable energy capital flows.

Control variables include GDP per capita, real exchange rate, urbanisation (Rural population (%) of total population) and interest rate, which explain the performance and stability of every economy. These variables influence investment and renewable energy consumption in each country and are economic indicators that drive capacity in each country [58]. Data for the control variables were sourced from World Development Indicators (WDI) database at the World Bank and International Financial Statistics.

Empirical strategy

This study adopts the dynamic generalised method of moments (GMM) estimator proposed by Arellano and Bond [6]. This method is used in controlling endogeneity problems by exploiting the data's time series variations and controlling for unobserved country-specific effects. Based on this technique, we set a model where the dependent variable depends on its lag and a vector of observations of the independent variables. Further, a two-step GMM is employed instead of the one-step GMM because of its ability to control heteroscedasticity and autocorrelation while capturing omitted variable problems and measurement errors [15]. The panel data are expressed in its general form as:

$$Y_{\mathrm{it}} = \beta_1 Y_{\mathrm{it}-1} + \beta_2 X_{\mathrm{it}} + \beta_3 Z_{\mathrm{it}} + \mu_i + \partial_{\mathrm{t}} + \varepsilon_{\mathrm{it}} \quad (1)$$

where subscripts i and t represent individual country and time dimensions, respectively; Y_{it} represents the dependent variable while $\mathrm{Y}_{\mathrm{it}-1}$ represents the lag of the dependent variable; X_{it} represents the independent variables, Z represents a vector of the control variables; β represents the parameters to be estimated; μ_i represents the country-specific fixed effects; ∂_{t} represents the time fixed effect; and $\varepsilon_{\mathrm{it}}$ is the idiosyncratic error term. Following the model by Adeleye et al. [3] and modifying them, our specific model is stated as:

$$\begin{aligned}\mathrm{REI}_{\mathrm{it}} &= \beta_1 \mathrm{REI}_{\mathrm{it}-1} + \beta_2 \mathrm{INST}_{\mathrm{it}} + \beta_3 \mathrm{IR}_{\mathrm{it}} \\ &+ \beta_4 \mathrm{ER}_{\mathrm{it}} + \beta_5 \mathrm{URB}_{\mathrm{it}} + \beta_6 \mathrm{GDP}_{\mathrm{it}} \\ &+ \mu_i + \partial_{\mathrm{t}} + \varepsilon_{\mathrm{it}}\end{aligned} \quad (2)$$

where REI denotes renewable energy capital flows; $\mathrm{REI}_{\mathrm{it}-1}$ represents the one-period lag of renewable energy capital flows; INST is the institutional quality variable proxied as the economic freedom index; IR represents interest rate; ER represents exchange rate; URB represents urbanisation; and GDP represents the gross domestic product. GDP and REI are measured in their log form.

It is important to note that incorporating the lagged term of the dependent variable in the regression model may cause endogeneity problems since the lagged dependent variable depends on the lagged error term, which is a function of the country-specific fixed effects, therefore validating the adoption of the GMM estimator. To assess the consistency of the system GMM estimator, the Hansen and Sargan test of over-identifying restrictions was evaluated to test the overall validity of the instruments [6, 15].

The study further investigated the relationship between institutional quality and renewable energy capital flows by examining the nonlinearities. To achieve this, Eq. (2) is expanded to include the quadratic square term of institutional quality in the regression model, which is specified as:

$$\begin{aligned}\mathrm{REI}_{\mathrm{it}} &= \beta_1 \mathrm{REI}_{\mathrm{it}-1} + \beta_2 \mathrm{INST}_{\mathrm{it}} + \beta_3 \mathrm{INST}_{\mathrm{it}}^2 \\ &+ \beta_4 \mathrm{IR}_{\mathrm{it}} + \beta_5 \mathrm{ER}_{\mathrm{it}} + \beta_6 \mathrm{URB}_{\mathrm{it}} \\ &+ \beta_7 \mathrm{GDP}_{\mathrm{it}} + \mu_i + \partial_t + \varepsilon_{\mathrm{it}}\end{aligned} \quad (3)$$

Here, REI denotes renewable energy capital flows; $\mathrm{REI}_{\mathrm{it}-1}$ represents the one-period lag of renewable energy capital flows; INST is the proxy for institutional quality variable; INST^2 is the quadratic term for institutional quality; IR represents interest rate; ER represents exchange rate; URB represents urbanisation; and GDP represents the gross domestic product. GDP and REI are measured in their log form.

To examine the nonlinear relationship between institutional quality and renewable energy capital flows, the inflexion point of the quadratic terms was estimated, following the formula given by Lind and Mehlum [41], who specified the inflexion point as $x^{\min} = -\widehat{\theta}_1 / 2\widehat{\theta}_2$. The criterion for interpreting the inflexion point is that negative values indicate a minimum function and a U-shaped relationship, while positive values indicate a maximum function and an inverted U-shaped relationship. Further, a U-shaped relationship is determined when the relationship is negative/decreasing at the start/low levels and positive/increasing at the end/high levels within the interval, while an inverted U-shaped relationship is when the relationship is positive/increasing at the start/high levels and negative/decreasing at the end/high level within the interval [41].

Results and discussion

Descriptive statistics

The descriptive statistics provide a summary of the variables used for the analysis. A summary of the average, variations and range is presented in Table 1. The mean score for the dependent variable, capital flows, is $99.70 (USD million), with a variation of 348.214 (USD million). This shows large variations in the renewable energy capital flows received amongst African countries. The minimum and maximum

Table 1 Descriptive statistics

Variable	Obs	Mean	SD	Min	Max
Capital flows	320	99.705	348.214	0.001	4961.211
Property rights	320	35.932	14.409	5.000	75.000
Government integrity	320	31.681	10.932	10.000	64.000
Tax burden	320	74.796	7.029	44.100	90.800
Government spending	320	73.132	14.074	0.000	95.200
Business freedom	320	57.041	11.162	30.000	85.000
Monetary freedom	320	70.582	14.78	0.000	90.400
Trade freedom	320	67.58	8.78	34.000	89.000
Investment freedom	320	48.938	17.31	0.000	135.000
Financial freedom	320	43.438	15.067	10.000	70.000
Economic freedom index	320	55.838	8.122	21.400	72.000
Interest rate	320	2.622	0.587	0.642	4.181
Exchange rate	320	1.029	0.232	0.619	2.395
Urbanisation	320	36.801	15.231	14.786	72.052
GDP	320	2625.158	4113.192	111.9272	28,305.22

values are 0.001(USD million) and 4961.211(USD million), respectively. The institutional quality variable measured by the index of economic freedom (EFI) has a mean of 55.838 and minimum and maximum values of 21.400 and 72.000, respectively. This score is slightly above the expected average of the index (50) and indicates that most countries in this study have made significant progress towards improving their institutional landscape. Property rights, government integrity, investment freedom and financial freedom have average scores that are below the threshold compared to the rest of the variables.

For instance, government integrity which measures the level of the systemic corruption of government institutions and decision-making, has an average of 31.681, reflecting that corruption is high in most African countries. The average score for financial freedom reflects strong government interference in the financial sector, whereas investment freedom suggests that most African countries have imposed restrictions on investments. The average (73.132) for government spending suggests that most countries in this sample have high government spending, a common trait in developing countries. Tax Burden, which reveals the overall level of taxation imposed by all levels of government, has an average of 74.796. This is evidence of the high level of taxation in most countries in SSA at all levels of government. The interest rate and exchange rate values are 2.622 and 1.029, respectively. Urbanisation, which describes the movement from rural to urban areas, recorded an average value of 38.801, whereas the average GDP per capita was 2625.158.

The correlation matrix indicates that the independent variables are not highly correlated, as shown in Table 7. Therefore, there is no multicollinearity issue, and the variables are considered fit to be used in the regression. The correlation between some institutional quality variables is also high, which means improvements in the variables will positively influence other institutional quality variables. Therefore, countries can benefit from institutional complementarities.

Empirical results and discussions

The linear relationship between institutional quality and renewable energy capital flows

This section provides the empirical results on the direct effect of institutional quality on renewable energy finance. A regression analysis that includes the index of economic freedom was analysed, as shown in Table 2. A dynamic model approach was used to investigate this relationship using the system GMM estimates and xtabond2 command in Stata 13 [6]. The results in Table 2 present that the lag of the dependent variable is positive and statistically significant at 1%, irrespective of the model specification. The results show that the past energy investment level strongly predicts its current level. That is, renewable energy capital flows are somewhat path-dependent; hence, previous years' energy investment strongly influences the energy investment of subsequent years. This implies that countries that receive high investment in renewable energy are more likely to experience high renewable energy capital flows in the future. The significant lag-dependent value also justifies the use of the dynamic model. To estimate the effect of institutional quality on renewable energy capital flows, a regression analysis that includes the index of economic freedom and the various indicators of the index was analysed, as shown in Table 2.

The empirical evidence further reveals a positive relationship between institutional quality and renewable energy capital flows. This relationship is statistically significant at a 5% significance level. This means that countries with strong institutional quality can attract investments in renewable energy. The positive relationship also means any effort by a country to improve its institutions would be rewarded by an increase in investor confidence in the renewable energy sector [7]. Therefore, African countries should ensure a strong institutional environment to promote investments in renewable energy. According to Ragosa and Warren [50], a country's investment environment is a key determinant for cross-border investments in renewable energy. Hence, recommend strong institutions.

In addition, institutional quality factors such as tax burden, government spending, monetary freedom and

Table 2 Impact of institutional quality on capital flows (system GMM estimates)

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
L. capital flows	0.246***	0.248***	0.230***	0.209***	0.239***	0.241***	0.225***	0.234***	0.271***	0.252***
	(0.0618)	(0.0550)	(0.0446)	(0.0447)	(0.0549)	(0.0654)	(0.0578)	(0.0615)	(0.0551)	(0.0531)
Interest rate	0.466*	0.899**	0.615**	0.823***	1.257**	0.355*	0.391**	0.127	1.396**	1.209**
	(0.242)	(0.400)	(0.268)	(0.266)	(0.521)	(0.170)	(0.170)	(0.224)	(0.590)	(0.464)
Exchange rate	1.675***	3.222***	4.163***	2.653***	3.376***	5.091	2.247***	2.321***	4.411***	4.091***
	(0.553)	(0.786)	(1.042)	(0.781)	(0.665)	(3.769)	(0.583)	(0.491)	(1.274)	(1.070)
Urbanisation	−0.0331**	−0.0209*	−0.00968	0.00175	−0.0371**	0.0115	−0.0121	−0.00586	−0.00858	−0.00742
	(0.0142)	(0.0101)	(0.00703)	(0.00823)	(0.0149)	(0.0332)	(0.0134)	(0.0123)	(0.00600)	(0.00597)
GDP	−0.0698	0.179	0.568**	0.376	0.0354	−0.112	−0.0772	−0.0379	0.575*	0.318*
	(0.141)	(0.111)	(0.242)	(0.246)	(0.116)	(0.133)	(0.107)	(0.136)	(0.300)	(0.177)
Property rights	0.0413									
	(0.280)									
Government integrity		1.271								
		(1.112)								
Tax burden			0.223***							
			(0.0590)							
Government spending				0.0663***						
				(0.0122)						
Business freedom					4.384					
					(2.742)					
Monetary freedom						0.0120***				
						(0.00276)				
Trade freedom							0.0408**			
							(0.0160)			
Investment freedom								0.0161***		
								(0.00412)		
Financial freedom									0.00398	
									(0.0114)	
Economic freedom index										0.0756**
										(0.0337)
Constant	−465.7***	−9.409	−25.34***	−11.27***	−22.20*	−236.1	−3.841***	−314.7**	−11.17**	−12.57**
	(109.4)	(5.498)	(7.703)	(3.832)	(12.18)	(233.8)	(1.135)	(134.4)	(5.160)	(5.247)
Observations	298	298	298	298	298	298	298	298	298	298
GMM instrument lag	1	1	1	1	1	1	1	1	1	1
Country and time dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
F Stat [*P* value]	24.57 (0.000)	2517.12 (0.000)	41.58 (0.000)	363.79 (0.000)	626.41 (0.000)	134.14 (0.000)	63.07 (0.000)	337.99 (0.000)	751.91 (0.000)	343.68 (0.000)
AR(1)	−3.64	−3.69	−3.49	−3.54	−3.46	−3.54	−3.54	−3.64	−4.08	−3.86
[*P* value]	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
AR(2)	0.76	0.81	0.44	0.54	0.61	0.69	0.73	0.70	0.81	0.78
[*P* value]	(0.452)	(0.418)	(0.658)	(0.594)	(0.545)	(0.491)	(0.468)	(0.486)	(0.416)	(0.435)
Hansen test [*P* value]	12.36 (0.577)	14.99 (0.379)	12.10 (0.598)	15.13 (0.369)	12.74 (0.547)	13.94 (0.454)	17.04 (0.468)	13.35 (0.499)	13.74 (0.469)	13.32 (0.402)
Sargan test	16.02	19.00	18.79	17.52	19.13	16.04	18.69	15.68	19.03	18.86
[*P* value]	(0.312)	(0.165)	(0.173)	(0.229)	(0.160)	(0.311)	(0.177)	(0.333)	(0.164)	(0.171)
Number of groups	20	20	20	20	20	20	20	20	20	20

Standard errors in parentheses; ***, ** and * denote significance level at 1%, 5% and 10%, respectively; GDP represents gross domestic product; economic freedom index represents the proxy for institutional quality investment freedom reflect a significant positive relationship with renewable energy capital flows at 1%. This is further affirmed by the correlation analysis in Table 7, which presents a positive association between renewable energy investment and tax burden, government spending and monetary and investment freedom. The significant positive effect of tax burden suggests that an increase in tax revenue, as suggested in the descriptive analysis, leads to an increase in government revenue which helps the government to meet the needs of citizens and organisations, which provides an avenue to support renewable energy finance. However, this must be done in a more controlled manner, as an undeterred tax increase is likely to adversely impact economic activities [18]. High government spending is a common trait in many African countries. The coefficient estimates suggest that an increase in government spending boosts growth and development, which affect every aspect of the economy, including the energy sector. Therefore, governments should ensure the efficient use of their financial resources to develop the overall economy and improve investment in renewable energy. Also, the coefficient values of monetary and investment freedom indicate that these factors are essential for the efficiency of investment in renewable energy in Africa. These significant positive results suggest the need for an open and market-efficient business environment to receive new capital inflows into renewable energy.

Also, trade freedom has a significant positive effect on renewable energy capital flows. Moreover, property rights, government integrity, business freedom and financial freedom reveal an insignificant positive relationship, indicating that their effect on renewable energy capital flows is not strong. The positive relationship for government integrity reveals that low corruption can lead to renewable energy investment. This aligns with Asiedu and Freeman [8], who reveals that government integrity positively affects investment. The positive relationship for property rights denotes that improved ownership structures can attract more investments, suggesting that government must develop its legal framework to protect property rights [45]. The findings indicate that countries with high institutional quality attract higher investments than countries with poor institutional quality. The study suggests that countries in Africa must improve their business environment to attract more investors. Regarding the control variables, interest and exchange rates show a positive and significant relationship with renewable energy capital flows. This is consistent across all the models. Contrary to this finding, scholars assert that high exchange and interest rates weaken investment. However, Zhao et al. [59] argue that high interest rate stimulates local investment by foreign investors, which can substantially enhance investment in renewable energy. Moraghen et al. [46] support this assertion by explaining that a positive relationship is possible when there are low volatilities. GDP and urbanisation showed diverse impacts on energy capital flows and were mostly insignificant.

The nonlinear relationship

Table 3 presents the findings of the system GMM estimates of the quadratic dynamic panel model. The results indicate that the assumptions behind the use of GMM are met, confirming the robustness of the GMM results. As a rule of thumb, the point of inflexion can reflect positive

Table 3 Threshold impact of institutional quality

Variables	(1)	(2)
L. capital flows	0.252***	0.262***
	(0.0531)	(0.0561)
Economic freedom index	0.0756**	1.036*
	(0.0337)	(0.524)
Economic freedom index^2		−0.00983* (0.00504)
Interest rate	1.209**	0.881*
	(0.464)	(0.435)
Exchange rate	4.091***	3.187***
	(1.070)	(0.881)
Urbanisation	−0.00742	0.00495
	(0.00597)	(0.0109)
GDP	0.318*	0.354
	(0.177)	(0.254)
Constant	−12.57**	−33.85*
	(5.247)	(16.98)
Inflexion points		1.88**
Observations	298	298
GMM instrument lag	1	1
Country and time dummies	Yes	Yes
F Stat [*P* value]	343.68 (0.000)	285.76 (0.000)
AR(1)	−3.86	−3.60
[*P* value]	(0.000)	(0.000)
AR(2)	0.78	0.73
[*P* value]	(0.435)	(0.468)
Hansen test [*P* value]	13.32 (0.402)	12.77 (0.544)
Sargan test	18.86	18.37
[*P* value]	(0.171)	(0.191)
Number of groups	20	20

Standard errors in parentheses; ***, ** and * denote significance level at 1%, 5% and 10%, respectively; GDP

represents gross domestic product; economic freedom index represents the proxy for institutional quality; economic freedom index^2 is the quadratic term for the institutional quality index or negative values. Negative values indicate a minimum function and a U-shaped relationship, while positive values indicate a maximum function and an inverted U-shaped relationship [41]. The results from the table show that the lag values of the dependent variable are positive and statistically significant at 1%. This indicates that the current renewable energy finance is dependent on its past capital flows. Consistent with the results in Table 2, the study also finds a significant positive relationship for the linear term of institutional quality. The quadratic term of institutional quality, which is represented by the economic freedom index^2, is also observed to be negative and statistically significant. This supports the assertion that institutional quality has a nonlinear relationship with energy capital flows, which takes the form of an inverted U-shaped relationship. This shows that the relationship is not monotonous but changes over time. This is consistent with the quantile regression estimates (see Table 5 in the appendix), confirming similar patterns.

The coefficient estimates of the lagged dependent variables are significantly positive across the quantiles, evidencing the high time dependence of renewable energy capital flows in Africa. More so, institutional quality proxied by the economic freedom index shows a significant relationship in the 95th quantile. The interest rate is significantly negative in the 40th quantile but presents positive and significant results at high levels between the 60th and 95th quantile. This indicates that the possibility of investing in renewable energy will likely increase as the financial conditions improve. The positive values for the inflexion points support the inverted U-shaped relationship between institutional quality and energy capital flows in Africa. In terms of the control variables, the results for the variables are similar to the estimations in Table 2, which are mostly positive and statistically significant. This informs the potential relationship as predicted in the correlation analysis.

The nonlinear relationship may have several implications. The inverted U-shaped relationship reveals that institutional quality positively impacts renewable energy capital flows at its initial stages but turns negative in extreme cases. This implies that the impact of institutional quality on energy capital flows diminishes at a certain threshold point, confirming the findings of Kurul [39], who argue that the impact of institutional quality on investment is attained at a certain threshold level. The negative result in the extreme case may be because a highly regulated investment environment can impose barriers to investment, particularly foreign investments [35]. Therefore, investors may shy away from investing in such an environment. This is in line with the assertion made by Kar and Saha [36], who argue that advanced institutional quality associated with extra-legal dimensions may hinder energy investment. The nonlinear inverted U-shaped relationship may also be an indication of the underdeveloped system in Africa's institutional and energy system, which becomes obvious beyond the threshold level [3]. Therefore, the institutional quality structures are not robust enough to contribute to renewable energy finance in the long run. Hence, important measures and policies are needed to overcome the negative effect of institutional quality in extreme cases.

Diagnostic checks

A set of conventional econometric methods and procedures were followed to ensure the consistency, reliability, robustness and efficiency of the dataset. First, the study sought outliers by examining the descriptive statistics. No potential outlier was found. Second, multicollinearity was checked by observing the correlation table (see Table 7). The table reveals no presence of multicollinearity. The generalised method of moments estimation technique was adopted to deal with endogeneity problems. The Hansen test, Sargan test and *P* values of AR(2) provide evidence of the validity and reliability of the regression outputs.

Another form of robustness check is using another proxy for institutional quality, namely World Governance Indicators, which is often used in the literature [3, 48, 55]. This helps to describe the depth of institutional quality on renewable energy capital flows. These are collected from the World bank database and range from -2.5 (weak) to $+2.5$ (strong). An index was constructed using the six characteristics: the rule of law, voice and accountability, control of corruption, political stability, regulatory quality and government effectiveness. The six characteristics reveal a mix of positive and negative coefficients, as shown in Table 4. One notable difference is the case of political stability which predicts a significant negative relationship. This can be attributed to the high level of political instability in Africa. Also, uncertainties regarding an unpredictable political climate will likely slow economic growth and investment. Likewise, corruption shows a negative relationship, implying that a high level of corruption in Africa has the propensity to dampen investment in renewable energy. On the other hand, a positive effect was found for voice and accountability, government effectiveness, regulatory quality and the rule of law. The positive relationship indicates that the presence of a strong institutional framework in Africa can induce renewable energy investment. Our empirical results in Table 4 confirm the positive relationship and the nonlinearity (thus, inverted U-shaped relationship) between institutional quality and energy capital flows,

Table 4 Robustness analysis (system GMM estimates)

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
L. capital flows	0.301***	0.359***	0.303***	0.260***	0.239***	0.302***	0.232***	0.201**
	(0.0736)	(0.0590)	(0.0752)	(0.0626)	(0.0681)	(0.0752)	(0.0732)	(0.081)
Interest rate	0.472**	0.141	0.475**	0.277	0.190	0.498*	1.239	0.525
	(0.224)	(0.131)	(0.226)	(0.254)	(0.221)	(0.240)	(2.288)	(3.096)
Exchange rate	6.868*	2.733**	7.143*	1.648**	3.224	6.986*	4.729	4.338
	(3.811)	(1.029)	(3.895)	(0.576)	(4.450)	(3.871)	(3.792)	(3.834)
Urbanisation	0.0204	− 0.00318	0.0232	− 0.0234	0.00757	0.0221	0.0180	0.101**
	(0.0359)	(0.0106)	(0.0366)	(0.0143)	(0.0391)	(0.0367)	(0.0374)	(0.045)
GDP	− 0.269	0.158	− 0.230	0.0504	− 0.140	− 0.262	− 0.0798	− 0.492*
	(0.171)	(0.129)	(0.156)	(0.169)	(0.200)	(0.175)	(0.214)	(0.282)
Voice/accountability	0.190							
	(0.323)							
Corruption		− 0.500**						
		(0.177)						
Gov. effectiveness			0.00830					
			(0.339)					
Political stability				− 0.486**				
				(0.174)				
Regulatory quality					0.525*			
					(0.280)			
Rule of law						0.186		
						(0.419)		
Gov. index							0.114	0.136
							(0.168)	(0.352)
Gov. index^2								− 1.793**
								(0.672)
Inflexion point								2.48**
Constant	− 167.6	− 3.399**	− 161.9	− 402.7**	− 282.2	− 168.2	− 177.1	− 292.5
	(239.9)	(1.258)	(240.5)	(142.9)	(231.2)	(249.5)	(280.1)	(305.2)
Observations	298	298	298	298	298	298	298	298
GMM instrument lag	1	1	1	1	1	1	1	1
Country and time dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
F Stat [*P* value]	12.92 (0.000)	29.15 (0.000)	25.84 (0.000)	24.12 (0.000)	22.04 (0.000)	27.73 (0.000)	48.30 (0.000)	15.32 (0.000)
AR(1)	− 3.57	− 3.75	− 3.60	− 3.68	− 3.62	− 3.61	− 3.58	− 3.71
[*P* value]	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
AR(2)	0.79	0.99	0.78	0.82	0.74	0.79	0.64	0.33
[*P* value]	(0.431)	(0.323)	(0.433)	(0.411)	(0.458)	(0.431)	(0.520)	(0.556)
Hansen test [*P* value]	10.49 (0.726)	14.88 (0.533)	10.45 (0.729)	11.98 (0.608)	13.32 (0.501)	10.49 (0.726)	13.78 (0.468)	15.24 (0.292)
Sargan test	16.27	31.73	16.21	16.04	15.99	16.22	16.34	14.48
[*P* value]	(0.297)	(0.011)	(0.301)	(0.311)	(0.314)	(0.300)	(0.293)	(0.341)
Number of groups	20	20	20	20	20	20	20	20

Standard errors in parentheses; ***, ** and * denote significance level at 1%, 5% and 10%, respectively supporting the empirical findings in Table 3. Our specification test affirms the consistency and reliability of the results.

Conclusion and recommendations

This study contributes to the literature by exploring the relationship between institutional quality and renewable energy capital flows in Africa. This is motivated by the scanty literature on institutional quality and energy capital flows in Africa. Also, the growing call from environmentalists for countries to accelerate their transition to clean and modern renewable energy sources in this region is a key motivator for this study. Using annual data for 20 countries in Africa from 2002 to 2017, the paper examined the linear and nonlinear relationship between institutional quality and renewable energy capital flows. The empirical relationship was analysed using the generalised method of moments (GMM) estimation technique with year and country dummies to control the year and country effects for a robust result.

The empirical findings suggest that institutional quality has a significant propelling effect on renewable energy capital flows. In addition, we find that institutional quality factors such as tax burden, government spending, monetary freedom, trade freedom and investment freedom positively and significantly impact renewable energy capital flows. The results suggest that institutional quality contributes to renewable energy capital flows. Thus, strong institutions induce investments in renewable energy. This can be achieved when the government promotes an investor-friendly environment that incentivises investment. We also find that the nexus between institutional quality and energy capital flows exhibit nonlinearity. The inflexion point further indicates that the relationship is not linear but nonlinear, taking an inverted U-shaped relationship. This implies that the enhancing effect of institutional quality on energy capital flows is realised at a certain threshold level. Beyond the threshold level, the impact of institutional quality on energy capital flows diminishes. The empirical estimates from the quantile regression support this result, affirming that institutional quality dampens energy capital flows at higher levels.

To address this problem, the governments of Africa need to implement important measures and policies to tame the adverse effect of institutional quality at higher levels. This can be done by monitoring the institutional environment to ensure that barriers that come with a highly regulated institutional environment are properly managed to promote renewable energy investment. This includes managing the extra-legal environment, which hinders renewable energy capital flows due to strong institutions. Also, a well-developed strategic plan that considers environmental or energy issues and promotes a friendly environment for renewable energy capital flows should be encouraged so investors do not shy away from such an environment.

The study further recommends that countries that want to enhance investment in renewable energy should develop strong institutions and reinforce their regulatory frameworks. Strong institutions can improve societal welfare by reducing political, social and economic unpredictability and boosting trust and investment in renewable energy. In addition, institutional quality factors such as tax burden, government spending, monetary freedom, trade freedom and investment freedom should be restrengthened to realise the full benefits of institutional quality on renewable energy investments and, ultimately, economic growth. This can be supported by providing tax rebates and credits to promote the use and investment in renewable energy. Policymakers should also understand the nonlinear impact of institutional quality on renewable energy investments and identify the optimal level where institutional quality enhances renewable energy investments. They should also introduce policy reforms that will minimise any adverse effects of institutional quality on renewable energy investments in the long run. Lastly, they should improve institutions that regulate the business, regulatory and financial environment to attract more investors. For future studies, this paper suggests that scholars further investigate this relationship using a large dataset and consider the bidirectional causality between institutional quality and renewable energy capital flows. The dynamic threshold estimation technique could also be employed to determine the threshold level at which institutional quality affects renewable energy capital flows.

Appendix

See Tables 5, 6, 7.

Table 5 Quantile regression

Variables	Q.20	Q.40	Q.60	Q.80	Q.95
L.Capital flows	0.516***	0.656***	0.386***	0.144**	0.0758**
	(0.0174)	(0.0332)	(0.0346)	(0.0624)	(0.0344)
Economic freedom index	0.111***	0.116**	0.125***	0.0937	0.326*
	(0.0249)	(0.0504)	(0.0431)	(0.144)	(0.169)
Economic freedom index^2	−0.00116***	−0.00118**	−0.00126**	−0.00114	−0.00433***
	(0.000264)	(0.000596)	(0.000519)	(0.00137)	(0.00167)
Interest rate	0.380***	−0.263***	0.863***	0.981***	1.165***
	(0.0979)	(0.0611)	(0.165)	(0.260)	(0.276)
Exchange rate	−2.363***	−0.414	0.968***	0.724	0.238
	(0.828)	(0.345)	(0.324)	(0.538)	(0.318)
Urbanisation	−0.0109	−0.0159*	−0.0110**	−0.0101	0.0234**
	(0.00717)	(0.00821)	(0.00516)	(0.00844)	(0.0117)
GDP	0.323***	0.0979	0.0782	−0.803	0.0385
	(0.0539)	(0.0713)	(0.0965)	(0.500)	(0.136)
Inflexion point	0.94*	0.75*	1.15	2.43**	0.43
Observations	298	298	298	298	298
Number of groups	20	20	20	20	20

Standard errors in parentheses; ***, ** and * denote significance level at 1%, 5% and 10%, respectively; GDP represents gross domestic product; economic freedom index represents the proxy for institutional quality; economic freedom index^2 is the quadratic term for the institutional quality index

Table 6 List of countries

Algeria	Mozambique
Botswana	Namibia
Burkina Faso	Nigeria
Congo DR	Rwanda
Egypt	Senegal
Ethiopia	South Africa
Ghana	Tanzania
Kenya	Uganda
Malawi	Zambia
Mali	Zimbabwe

Table 7 Correlation table

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
(1) Capital flows	1.000														
(2) Economic freedom ind	0.024	1.000													
(3) Property Rights	−0.041	0.832	1.000												
(4) Government integrity	−0.035	0.522	0.431	1.000											
(5) Business freedom	−0.092	0.671	0.610	0.463	1.000										
(6) Tax burden	0.231	0.278	0.177	−0.058	0.125	1.000									
(7) Government spending	0.291	0.321	0.144	−0.205	0.029	0.126	1.000								
(8) Monetary freedom	0.048	0.683	0.551	0.145	0.339	0.136	0.471	1.000							
(9) Trade freedom	0.163	0.568	0.321	0.438	0.407	0.055	0.143	0.349	1.000						
(10) Investment Freedom	0.019	0.576	0.455	0.414	0.264	0.162	0.065	0.444	0.313	1.000					
(11) Financial freedom	−0.039	0.801	0.687	0.397	0.453	0.272	0.095	0.432	0.432	0.523	1.000				
(12) Interest rate	0.036	−0.139	−0.112	−0.205	−0.212	0.221	−0.111	−0.226	−0.121	0.121	0.055	1.000			
(13) Exchange Rate	0.189	−0.012	−0.098	−0.121	0.021	0.092	0.231	0.037	0.039	−0.130	−0.089	−0.074	1.000		
(14) Urbanisation	−0.125	0.193	0.209	0.459	0.386	−0.058	−0.261	0.050	0.135	0.129	0.145	−0.240	−0.242	1.000	
(15) GDP	−0.004	0.350	0.274	0.417	0.467	0.100	−0.220	0.152	0.364	0.114	0.357	−0.171	−0.047	0.636	1.000

Abbreviations

SSA	Sub-Saharan African
UNEP	United Nations Environment Programme
FI	Finance initiative
GMM	Generalised methods of moments
IEA	International Energy Agency
AFREC	African Energy Commission
AU	African Union

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Author contributions
A.D. was involved in conceptualisation, introduction, literature review, and interpretations and discussion. S.S.H. was responsible for literature review, data analysis, methodology, interpretation and discussion, and conclusion and recommendations.

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