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Renewables and institutional quality mitigate environmental degradation in Somalia

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A B S T R A C T

Mitigating environmental degradation is a global target for every nation amidst its negative consequences on health, economy, and society. However, little is known about factors associated with reducing environmental pollution in the least developed nations. More specifically, empirical studies on renewables-institutional quality-environmental degradation nexus in Somalia are completely limited in the existing literature. To fill this gap, we investigate the effect of renewables and institutional quality on environmental degradation in Somalia, using data spanning 1990 to 2017. The autoregressive distributed lag model (ARDL) and granger causality are applied to examine the relationships and causality between parameters of interest. The long-run results demonstrate that renewable energy and institutional quality enhance environmental quality. While growth in capital declines environmental degradation, population growth, and economic development hamper environmental quality. Besides, the granger causality indicates unidirectional causality from institutional quality to environmental degradation. However, no causality is observed from renewable energy to environmental degradation and vice versa. Our empirical assessment suggests good governance that improves institutional quality and energy policies, viz. enhancing the share of renewables in the energy mix.

1. Introduction

Environmental degradation is considered one of the most severe environmental phenomena facing the world in recent years. This has become a global concern owing to the importance of environmental protection and sustainability. The coupling effect of economic growth and environmental degradation may lead to more environmental concerns with rising levels of economic productivity [1]. The environmental Kuznets curve (EKC) hypothesis (i.e., inverted U-shaped relationship between environmental pollution and economic development) posits growth in the early stages deteriorates environmental quality, however, environmental quality improves after exceeding a threshold of income [2]. The environmental implications of the EKC hypothesis are more of a concern to developing and least developed countries. Yet, there is always a trade-off between economic growth and environmental protection in the implementation of developmental initiatives [3].

Environmental deterioration in the least developed countries is demonstrated by the rate of deforestation, which is predominantly the main driver of environmental degradation. Deforestation directly affects economic activities and poses a threat to the livelihoods of forest-dependent populations [4]. On the other hand, deforestation constitutes approximately 20% of global CO_2 emissions, which is greater than the combination of the world's vehicles, vessels, and planes [5,6]. A study conducted by Minnemeyer et al. [7] reported low-cost solutions to curb deforestation could decline emissions by more than 40%. Accordingly, less than 100 USD/year investment could reduce a ton of CO_2 emissions. Failure to institute climate change policies is projected to increase anthropogenic GHG emissions by ~50% by 2050——of which energy-related CO_2 emissions contribute 70% [8]. This implies increasing production and

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consumption of clean energy technologies such as renewables are critical to tackle long-term climate challenges while improving environmental sustainability [9–11]. However, the impact of mitigating options varies across countries depending on the share of clean energy in total energy mix. Most economies are gradually diversifying energy resources, increasing energy security, and reducing the reliance on fossil fuels through the adoption of renewables [12]. In contrast, the shift toward clean energy technologies in developing economies is hampered by institutional barriers [13].

Somalia is currently facing energy insecurity––as most urban and traditional households depend on traditional biomass namely charcoal and firewood––which accounts for about 82% of total energy utilization [14]. The unsustainable consumption pattern of traditional biomass has affected forest resources, leading to desertification and loss of grazing & arable land. For example, Somalia's forest area has declined from 13% of the total land area in 1990 to nearly ~9.5% by 2020 (see Fig. 1). Thus, approximately 2.2 million hectares of forest land were lost between 1990 and 2020. It is estimated that ~95% of total energy consumed by lightning and other industries is produced from fossil fuels. Somalia is rich in renewable energy resources including solar, wind, hydropower, and vast geothermal energy––but political, financial, and institutional factors have limited the exploitation of these renewables. Despite the long-running civil war and low development, Somalia has the potential to achieve sustainable development and contribute to the reduction of GHGs.

Besides, improving institutional quality is key to enhancing environmental quality––i.e., by prioritizing regulatory institutions due to rise in income and attitudinal change toward environmental protection [15,16]. Contrary, environmental issues in developing countries are related to poor political-institutional quality, which weakens environmental protection by posing a bias in the adaptation and integration of existing government regulations [17]. The impact of institutional quality on environmental protection has been discussed extensively in the literature. Strengthening government institutions to enforce environmental laws is argued to improve environmental quality [18]. Institutional failure and/or weak governance, on the other hand, could hamper ecosystem vitality, causing permanent environmental harm [19]. Abid et al. [20] highlighted that environmental policies in developing countries tend to be less stringent. Somalia's civil war has negatively impacted the country's overall governance, which has affected the management of the energy sector and environment. Before the civil war, there was a system (even though it was not fully functional) that controlled the use of energy but was disrupted during the civil war, hence, affecting energy and environmental protection.

Fig. 1. Somalia's Forest Area (% of land area). Data source: World Bank (2022).

Despite the importance of developing more coherent policies to tackle the growing environmental issues, existing literature that investigates this theme is limited in Somalia. To the best of our knowledge, no study has empirically examined the influence of institutional quality and renewables on environmental performance in Somalia. The very few studies that explored these relationships in developing economies have not only produced inconsistent results but also excluded Somalia from the sample [3,21–24]. Thus, there is lack of either country-specific or cross-countries empirical studies that include Somalia. This study attempts to fill this gap and contribute to global discussion on environmental quality with a perspective from Somalia. This study adds several contributions to the growing literature: First, the study simultaneously examines the role of both renewables and institutional variables on environmental quality. Second, the EKC framework is incorporated into the environmental degradation-renewables-institutional quality nexus. Third, this undertaking considers the nexus illustrated within the country-specific (Somalia) framework which sheds light on the scope of this examination. Finally, more robust estimation techniques based on ARDL, fully modified ordinary least square (FMOLS), and causality test are employed to suggest more comprehensive policy recommendations from the EKC hypothesis in Somalia.

The subsequent sections include relevant literature on renewable-institutional effects on environmental quality, econometric methods with empirical specification, empirical findings & discussion, and conclusion with policy implications.

2. Literature review

The empirical studies that investigate the principal factors that affect environmental degradation are fast expanding. This scope has been explored in various dimensions including institutions–environment quality link, energy – environmental degradation nexus, the EKC, and pollution haven (PH) hypotheses. However, this study only presents relevant literature related to renewables–environmental degradation nexus, and institutional–environmental quality nexus, which is relevant to our objectives.

2.1. Renewable energy and environmental degradation

Although several empirical studies have examined the linkage between renewables and environmental quality in both developed and emerging economies, nevertheless, these studies lack consensus due to econometric techniques employed, the nature of the data set utilized, and indicators used to measure environmental quality. Using an ARDL method, Usman et al. [25] assessed the impact of renewable energy on environmental degradation in the US for the period 1985Q1 and 2014Q4. The empirical analysis affirmed the positive contribution of renewables on environmental quality. Likewise, Al-Mulali et al. [26] reported renewable energy significantly declines environmental degradation in Kenya. In a study using Turkey as a case study, Karasoy & Akçay [12] reported an increase in consumption of renewable energy reduces CO_2 emissions in both the short-run and long-run. Another two empirical studies carried out in Pakistan reached the same conclusion that renewable energy significantly abates CO_2 emissions [27,28]. Moreover, Chen et al. [29] and Bélaïd & Youssef [30] found similar findings in China and Algeria, respectively. For

Malaysia, Bekhet & Othman [31] found an indirect association between renewable energy and CO_2 emissions. Likewise, using data from Tunisia, Cherni & Jouini [32] confirmed the hypothesis that renewable energy promotes environmental quality by abating CO_2 emissions.

For panel studies, Ahmad et al. [17] explored the relationship between renewable energy and environmental degradation in five Northwestern Chinese provinces using nonlinear ARDL bounds testing approach. The empirical analysis revealed that renewable energy utilization improves environmental quality. Moreover, another panel data conducted in OECD countries by Shafiei & Salim [33] showed renewable energy consumption is associated with decreasing CO_2 emissions. Similarly, Paramati et al. [34] reached a similar conclusion by examining the same relationship for developing countries from 1990 to 2012. In a regional study of 16 European countries (EU) between the 1996–2014 period, Bekun et al. [35] reported that renewable energy has a favorable effect on environmental quality. In another two panel studies conducted in SSA countries, Jebli et al. [24] and Apergis et al. [22] observed the effect of increasing renewable energy consumption declines CO_2 emissions. Also, data from South American countries supported these findings [36].

In contrast to these findings, other studies found the exact opposite results. For instance, Apergis et al. [37] found renewable energy usage increases CO_2 emissions in 19 developing and developed countries. A similar result was suggested by Jebli & Youssef [38], and Nguyen & Kakinaka [39] for their study of 5 North African and low-income countries, respectively. Moreover, Al-Mulali et al. [40] argued that rising renewable energy consumption has no significant impact on CO_2 emissions in Vietnam. Farhani & Shahbaz [41], in their study of 10 Middle East and North Africa (MENA) countries pointed out that increasing renewable energy utilization increases CO_2 emissions. Likewise, Wang & Dong [21] refuted the claim that an increase in renewable energy consumption abates CO_2 emissions using panel data from 14 SSA countries for the period 1990–2014.

2.2. Institutional quality and environmental degradation

Currently, the empirical studies on environmental quality and institutional quality are fast expanding but still limited in least-developed countries with no conclusion so far. A recent study carried out in 66 developing countries by Azam et al. [42] investigated the effect of institutional variables on various environmental indicators like forest area, and CO_2 emissions for the period 1991 and 2017. The main empirical findings revealed institutional quality matters for the environment. Similarly, Ali et al. [43] revealed the same findings in 47 developing countries. Using panel data of 40 SSA countries based on generalized method of moments (GMM) technique, Ibrahim & Law [3] reported that institutional quality enhances environmental quality. Similarly, institutional quality is reported to affect environmental quality in 47 developing countries [43].

In the same vein, Akhbari & Nejati [44] studied the nexus between institutional quality (measured in corruption) and environmental degradation (measured in CO_2 emissions) using cross-country data from developed and developing nations. The study found that a decrease in the corruption level contributed to the decline of CO_2 emissions in developing countries, but had no significant impact in developed nations. Institutional quality is confirmed to increase environmental degradation for each unit of increase in corruption levels across 64 developing countries [19]. Wawrzyniak & Doryń [15] also supported these findings after exploring the same issue for a panel of 93 countries from 1995 to 2014. Measuring government effectiveness and corruption for institutional quality, they noticed a significant decrease in CO_2 emissions for countries with strong effective governments, whereas a steady rise in CO_2 emissions was observed for countries with low-quality institutions. Moreover, Lau et al. [45] backed the argument that institutional quality is key to curbing CO_2 emissions in Malaysia. Another panel data conducted in developing countries by Arvin & Lew [46] analyzed the link between institutional quality (measured by democracy) and environmental quality (measured by CO_2 emissions, water pollution, and deforestation damage). The empirical results showed mixed findings as the result is sensitive to various measures used for environmental quality.

3. Materials and methods

3.1. Data

This study utilized annual time series data spanning 1990 to 2017. The availability of data series determines the sampling observations. The data were extracted from the World Bank, the Organization of Islamic Cooperation (OIC – SESRIC), and Freedom House. The data series include deforestation (used as proxy for environmental degradation), renewable energy, institutional stability, economic growth, total population, and gross fixed capital formation (Table 1).

3.2. Econometric methodology

This study employed the ARDL model – postulated by Pesaran et al. [47], – to achieve the outlined objective. This method outperforms other cointegration methods namely Johansen & Juselius cointegration method, and Engle & Granger in several ways. First, the ARDL method is versatile in small-sample observations compared to other cointegration methods. Second, the ARDL method could regress series that are integrated at level [I (0)], first-difference [I (1)], or a combination of both. Third, it is possible to estimate the short- and long-run cointegration simultaneously without affecting the long-run cointegration results. The linkage between environmental degradation, renewable energy, institutional quality, economic growth, squared term of economic growth, total population, and capital in a multivariate model can be specified as:

$$lnED_t = \beta_0 + \beta_1 lnRE_t + \beta_2 lnIS_t + \beta_3 lnRGDPC_t + \beta_4 lnRGDPC^2{}_t + \beta_5 lnPOP_t + \beta_6 lnK_t + \varepsilon_t \quad (1)$$

where $lnED_t$ is the natural logarithm (ln) of environmental degradation, $lnRE_t$ is the natural logarithm of renewable energy, $lnIS_t$ is a natural logarithm of institutional stability, $lnRGDPC_t$ is the natural logarithm of real GDP per capita, $lnRGDPC^2$ represents the natural logarithm of the square term of real GDP per capita and ε_t is the error term. To avoid issues related to heteroskedasticity, non-normality, and misspecified functional form, all variables were log-transformed.

We used the ARDL method to test the long- and short-run cointegration among the regressand and regressors. Following the empirical work of Sarkodie & Adams [48], Shah et al. [49], the ARDL cointegration equation can be specified as:

Table 1
Variables' descriptions.

Parameters	Code	Measurement	Source
Environmental Degradation	ED	Arable Land (Deforestation) is a proxy for environmental degradation	World Bank
Renewable Energy	RE	Percent of total final energy consumption	World Bank
Population	POP	Total Population	World Bank
Institutional Stability	IS	Combination of Political and Civil Rights.	Freedom House
Economic growth	RGDPC	Real Gross Domestic Product Per Capita (Constant 2010)	SESRIC
Gross capital formation	K	In Million US$	SESRIC

$$\begin{aligned}\Delta lnED_t = &+\alpha_0 + \beta_1 lnED_{t-1} + \beta_2 lnRE_{t-1} + \beta_3 lnIS_{t-1} \\ &+ \beta_4 lnRGDPC_{t-1} + \beta_5 lnRGDPC^2{}_{t-1} + \beta_6 lnPOP_{t-1} + \beta_7 lnK_{t-1} \\ &+ \sum_{i=0}^{q} \Delta\alpha_1 lnED_{t-k} + \sum_{i=0}^{p} \Delta\alpha_2 lnRE_{t-k} + \sum_{i=0}^{p} \Delta\alpha_3 lnIS_{t-k} \\ &+ \sum_{i=0}^{p} \Delta\alpha_4 lnRGDPC_{t-k} + \sum_{i=0}^{p} \Delta\alpha_4 lnRGDPC^2{}_{t-k} \\ &+ \sum_{i=0}^{p} \Delta\alpha_5 lnPOP_{t-k} + \sum_{i=0}^{p} \Delta\alpha_5 lnK_{t-k} + \varepsilon_t \end{aligned} \tag{2}$$

where α_0 is the constant, $\alpha_1 - \alpha_7$ are the coefficient of the short-tun variables, $\beta_1 - \beta_7$ are the elasticities of long-run parameters, p shows the optimal lags of the regressors, q indicates the regressand's optimal lags, Δ is the first difference sign indicating short-run variables and ε_t is the error term.

The first step of the ARDL cointegration method entails bound testing which is regressed through Ordinary Least Square (OLS). The null hypothesis $(H_0): \beta_1 = \beta_2 = \beta_3 = \beta_4 = \beta_5 = \beta_6 = \beta_7 = 0|$ implies variables are not cointegrated in the long-run whereas the alternative hypothesis (H_1): $\beta_1 \neq \beta_2 \neq \beta_3 \neq \beta_4 \neq \beta_5 \neq \beta_6 \neq \beta_7 = 0|$ implies variables are cointegrated in the long-run. The Wald-F statistics and critical values were used to test the null hypothesis. The null hypothesis is discarded if the Wald-F statistics fall above the upper bound critical values——implying that the variables are related in the long-run and vice versa. Finally, if it falls between the two critical values – upper and lower – the null hypothesis remains inconclusive.

4. Empirical analysis and discussion

4.1. Descriptive analysis

We analyzed the characteristics of the data series using descriptive statistics presented in Table 2. Results in Table 2 report the mean of environmental degradation (13.89), renewable energy (4.52), real GDP per capita (4.58), population (16), institutional variables (1.9), and gross capital formation (9.14). Besides, gross capital formation and population have the highest maximum values of 19.4 and 16.4, respectively. All the variables are positively skewed except renewable energy and institutional variables. Population has the highest coefficient of standard deviation (0.22), which implies the normal values of population are far from its mean. The correlation of the sampled variables presented in Table 3 shows that renewable energy and population are positively associated with environmental degradation, whereas real GDP per capita, institutional quality, and domestic investment have a negative correlation with environmental degradation.

4.2. Unit root test

Testing the unit root properties is a prerequisite in time series modeling, specifically ARDL. Hence, Augmented Dickey-Fuller (ADF) and Philips perron (PP) tests were utilized to circumvent spurious regression results. The unit root analysis reported in Table 4 shows lnRGDPC and lnPOP are stationary at level [I (0)], whereas the remaining series has unit root. However, Table 4 reveals almost all the series are integrated at first-difference [I (1)]. Since none of the variables are stationary at second-difference I (2), we proceeded to estimate the bounds test cointegration.

Results of the bounds test presented in Table 5 examine the presence of long-run co-integration between environmental degradation and the regressors. However, the results show the Wald F-statistics (6.38) is above the upper bound critical value (4.73) at 5% significance level. This infers the variables are cointegrated in the long-run.

Estimating the long-run parameters comes into play after confirming the series are cointegrated in the long-run. The long-run coefficients of the parameters in Table 6 indicate the statistical significance of all regressors except the squared of economic growth. Table 6 shows that renewable energy and institutional quality promote environmental quality in the long-run. Specifically, 1% rise in renewable energy diminishes environmental degradation

Table 3
Correlation.

	lnED	lnRE	lnRGDPC	lnPOP	lnIS	lnK
lnED	1					
lnRE	0.3461	1				
lnRGDPC	−0.3083	−0.92104	1			
lnPOP	0.2757	0.8484	−0.6434	1		
lnIS	−0.6672	−0.2268	0.2388	0.0004	1	
lnK	−0.2105	−0.2362	0.5559	0.256	0.3328	1

Table 2
Descriptive statistics.

Stats	lnED	lnRE	lnRGDPC	lnPOP	lnIS	lnK
Mean	13.89679	4.523868	4.583197	16.08197	1.928808	19.14009
Median	13.85761	4.532698	4.519612	16.08320	1.945910	19.11551
Maximum	14.11562	4.547827	4.988526	16.43998	1.945910	19.47715
Minimum	13.81551	4.468241	4.498364	15.79307	1.871802	18.92412
Std Dev	0.084298	0.022504	0.146080	0.220517	0.031842	0.149052
Skewness	1.494525	−1.194237	1.972334	0.089590	−1.278019	0.426614
Jarque-Bera	11.71834	6.259611	22.66698	2.141575	7.223426	1.349033
p-value	0.002854	0.043726	0.000012	0.342739	0.027006	0.509403

Table 4
Unit root tests.

Variable	T-statistics	
	ADF	PP
lnED	-2.7243	-2.0227
lnRGDPC	-25.4733***	-3.0029
lnRE	-2.4484	-2.4059
lnIV	-1.7298	-1.7872
lnPOP	-4.7441***	-3.5288*
lnK	-1.7589	-3.6374**
ΔlnED	-3.8957**	-3.7735***
ΔlnRGDPC	-6.2791***	-6.1671***
ΔlnRE	-3.6264***	-3.6527***
ΔlnIV	-4.8560***	-4.8560***
ΔlnPOP	-4.6993***	-1.5077
ΔlnK	-5.8101***	-5.7660***

Notes: ***,**,* Indicate the significance level at 1%, 5%, and 10%. Δ denotes first-difference operator. The T-statistics reported are the intercept and trend.

Table 5
F-bound test.

Wald F-statistic	Level of Significance	Bounds test critical values	
		M (6)	
		I (0)	I (1)
6.3855	1%	4.824	6.56
	5%	3.326	4.73
	10%	2.752	3.922

Notes: Narayan's (2005) critical values are used to compare the Wald F-statistics. M = number of explanatory variables.

Table 6
Long-run results.

Regressors	Coefficient
Constant	−2.5992 (-0.1880)***
lnRE	−4.5704 (-3.0134)***
lnIS	−0.8782 (-4.8154)***
lnRGDPC	9.6614 (1.8850)*
$lnRGDPC^2$	−0.8267 (-1.5690)
lnPOP	1.0171 (5.8857)***
lnK	−0.5518 (-2.7862)**
Adjusted R-square	0.6575
Reset test	0.9504 [0.3551]
X^2sc	1.1591 [0.0603]
Jarque-Bera	5.5926 [0.0610]

Note: ***,**,* Indicate significance levels at 1%, 5%, and 10%. The T-statistics are reported in (..), *p-values* are in [..], and X^2sc represents the serial correlation.

by ~4.57% in the long-run. In the same vein, 1% improvement in institutional variables decreases environmental degradation by 0.87% in the long-run. The squared term of economic growth is statistically insignificant in the long-run, confirming the EKC hypothesis is invalid in Somalia. However, economic growth is statistically significant at 10% level. Thus, 1% increase in economic growth spur environmental degradation by 9.66% in the long-run. Moreover, 1% increase in population enhances environmental degradation by 1.01% in the long-run. On the contrary, 1% increase in domestic investment reduces environmental degradation by ~0.55% in the long-run. The adjusted R-squared reported in Table 6, shows 65% of variations in environmental degradation are explained by the explanatory variables.

Our results indicating the mitigating effect of renewable energy are corroborated by numerous studies that found renewable energy improves environmental quality. For instance, Shafiei & Salim [33], on OECD countries; Sarkodie & Adams [48], on South Africa, Usman et al. [25] on the US, Khan et al. [50], on panel countries, and Adebayo et al. [51] on Argentina. Moreover, Chien et al. [52], revealed that clean energy has a constructive role in mitigating CO_2 emissions in 10 Asian countries. In contrast to our results, other studies concluded that renewable energy does not play any significant role in reducing environmental pollution [40]. Other empirical results reported that clean energy escalates environmental pollution in several sampled countries [37]. This result is emphasized by Jebli & Youssef [38] in 5 North African countries, and Nguyen & Kakinaka [39] in low-income countries. Even though Somali's energy sector does not receive any support from the government, however, private sector leads the investment efforts. Investments from the private sector in renewable energy namely solar and wind are growing. Notably, Somalia has the highest potential resource of onshore wind power in Africa, which could generate energy between 30,000–45,000 MW. Moreover, solar power could be generated from over 2000/kWh/m^2, yet, the majority of these solar resources are untapped. This is attributed to several factors including poor infrastructure, inadequate investments, shortage of qualified labor, limited regulations, insecurity, and political instability [53,54].

Institutional quality with political opportunism enhances cooperative behavior among agents, making it possible for agents to internalize the externalities——which ultimately improves environmental quality. However, the collapse of the Somali central government in 1991 did not only undermine the economic production sectors but also impeded environmental quality. Charcoal trades – which were illegal during the existence of the central government became a primary source of trade, leading to the depletion of natural resources and deforestation of trees. However, this illegal trade was banned by United Nations (UN) – owing to efforts from the Somali government in 2012 [55]. Hence, the establishment of the federal government in 2012 received international recognition and further banned international efforts of trade exports involving Somalia charcoals——thus, dramatically reducing the unsustainable trade of charcoal. This effort tackled environmental pollution by reducing biodiversity loss due to tree preservation. This justifies our empirical results that improving institutional quality declines environmental degradation——which are further supported by several previous empirical studies [43–45]. Institutional quality implies strong government institutions. On the other hand, weak government institutions result in an increase in corruption levels which ultimately hampers environmental quality as evidenced by Masron & Subramaniam [19], across 64 developing countries. This result is further supported by Wawrzyniak & Doryń [15] in a panel of 93 countries.

Additionally, our results reveal that economic growth escalates environmental degradation in Somalia. The agricultural sector namely crops and livestock production is the main sector of the country's production [56,57] The absence of government rules and regulations on environmental sustainability has resulted in ineffective agricultural cultivation practices, rearing of livestock production, and vintage technologies that inhibit environmental quality. The failure to validate the EKC hypothesis in Somalia is consistent with previous studies that failed to find EKC in developing countries [58,59].

The short-run results reported in Table 7 show renewable energy and institutional variables are statistically insignificant. This implies that institutional quality and renewable energy have only a

Table 7
Short-run elasticities and error correction.

Regressors	Coefficient
Constant	5.2618 (4.3318)***
ΔlnRE	3.9138 (1.1159)
ΔlnRGDPC	4.2289 (3.8262)***
$\Delta lnRGDPC_{t-1}$	1.1926 (1.4138)
$\Delta lnRGDPC_{t-2}$	8.7776 (2.1621)**
$\Delta lnRGDPC^2_{t-1}$	7.3567 (2.0447)*
ΔlnPOP	15.679 (4.0075)***
ΔlnIS	0.3329 (0.5837)
ΔlnDI	−1.4517 (-3.1066)***
ECT_{t-1}	−0.9108 (-4.3357)***

Note: ***,**,* Indicate the significance level at 1%, 5%, and 10%. T statistics are reported in (..). Δ = differencing. ECT stands for error correction term.

long-term favorable effect on environmental quality. An increase in economic growth and squared term of economic growth by 1% significantly hamper environmental quality in Somalia by ~4.22% and 8.77% respectively in the short-run. The short-run results of population growth and domestic investment are consistent with the long-run findings. Thus, 1% increase in Somalia's population impede environmental quality by 15.6% in the short-run, whereas as 1% increase in domestic investment leads to the increase in environmental quality by 1.47% in the short-run. Besides, Table 7 shows a negative coefficient and statistically significant speed of adjustment (ECT). The ECT terms (i.e., −0.91) reaffirm the existence of long-run cointegration among the variables. This infers that the explanatory variables adjust the short-run shocks that occur in environmental degradation by ~91%.

4.3. Robust analysis

Reaching a conclusion based on the findings of a single method can lead to misspecified policy inferences. To account for this shortfall, we further employed FMOLS to check the ARDL long-run results reported in Table 8. The results demonstrate that most of the variables are insignificant except institutional quality. Even though all the variables have the same coefficient directions except domestic investment. We find that 1% improvement in institutional variables undermines environmental degradation by ~1.94% in the long-run. Thus, the FMOLS results verify the long-run results of the ARDL. To examine the reliability and robustness of the estimated results, we employed different measurements of diagnostic tests

Table 8
FMOLS Method.

Variable	Coefficient	T-Statistic
lnIS	−1.9413***	−5.7481
lnDI	0.4125	1.5478
lnPOP	0.1146	0.9292
lnRE	−3.4199	−1.0580
lnRGDPC	22.1536	1.4395
$lnRGDPC^2$	−2.3857	−1.4526
Constant	−26.270	−0.7894
R-squared	0.319130	
Adjusted R-squared	0.092173	
Mean dependent var	13.89917	

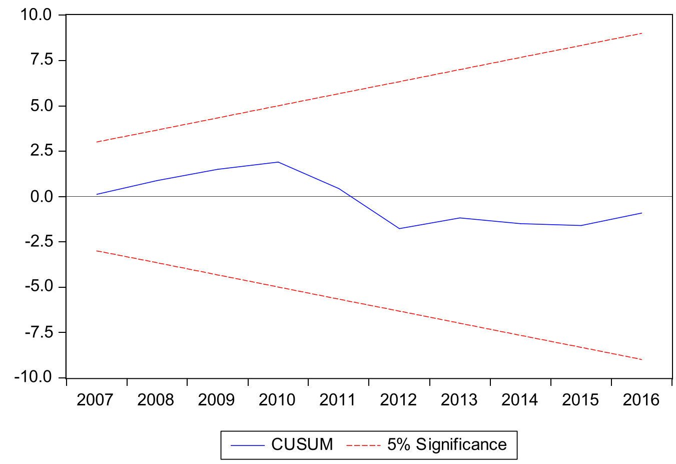

Fig. 2. Assessing parameter stability using CUSUM test.

namely serial correlation, normality test, and reset test. The diagnostic tests reported in Table 6 confirm the study has no issues with autocorrelation, model misspecification, and non-normality. In addition, we utilized CUSUM and CUSUM square tests to check the model stability. The plots in Figs. 2–3 confirm the parameters are stable over the period 1990–2017.

4.4. Granger causality

To detect the direction of causation among variables, we applied the Granger causality test reported in Table 9. We observe unidirectional causality from institutional quality to environmental degradation, renewable energy to population, and renewable energy to capital formation. The causality of institutional quality on environmental degradation confirms that institutional quality is critical for tackling environmental pollution. Bidirectional causality is found between economic growth and the square term of economic growth as apparently should be (i.e., since the square term of economic growth is a direct outcome of economic growth). Moreover, unidirectional causalities are detected from economic growth to population and capital. In the same vein, the square term of economic growth Granger causes population and capital. Interestingly, a bidirectional causality is found among population and capital. However, economic growth and square term of economic granger cause capital and population.

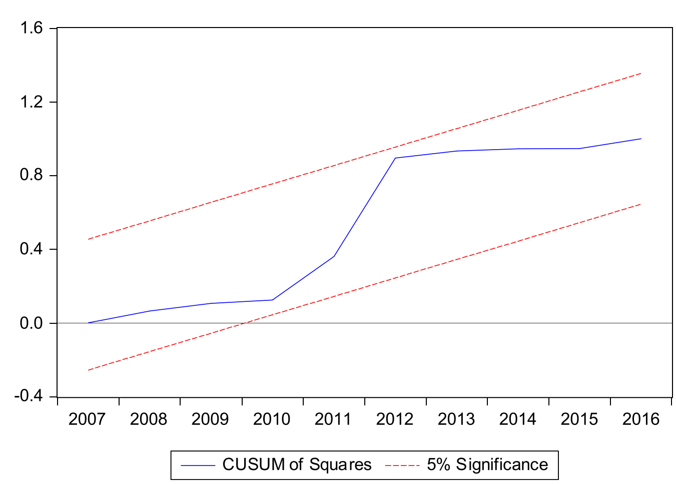

Fig. 3. Assessing parameter stability using CUSUM square test.

Table 9
Granger causality tests.

Null Hypothesis:	Obs	F-Statistic	Prob.
lnRE→lnED	24	2.12927	0.1464
lnED→lnRE		0.80645	0.4611
lnRGDPC→lnED	25	0.57049	0.5742
lnED→lnRGDPC		0.17216	0.8431
$lnRGDPC^2$→lnED	25	0.56387	0.5778
lnED→$lnRGDPC^2$		0.17299	0.8424
lnPOP→lnED	25	0.73478	0.4921
lnED→lnPOP		0.26260	0.7717
lnIQ→lnED	25	4.79172	0.0199
lnED→lnIS		1.67514	0.2125
lnK→lnED	25	0.31523	0.7332
lnED→lnK		0.30250	0.7423
lnRGDPC→lnRE	24	0.53366	0.5950
lnRE→lnRGDPC		0.07875	0.9246
$lnRGDPC^2$→lnRE	24	0.51454	0.6059
lnRE→$lnRGDPC^2$		0.09681	0.9082
lnPOP→lnRE	24	2.61907	0.0990
lnRE→lnPOP		5.17782	0.0160
lnIS→lnRE	24	2.55488	0.1041
LRE→lnIS		0.13756	0.8723
lnK→lnRE	24	0.31536	0.7333
lnRE→lnK		11.3670	0.0006
$lnRGDPC^2$→lnRGDPC	26	11.6880	0.0004
lnRGDPC→$lnRGDPC^2$		11.7788	0.0004
lnPOP→lnRGDPC	26	1.50146	0.2458
lnRGDPC→lnPOP		40.3261	0.0000
lnIS→lnRGDPC	26	0.30818	0.7380
lnRGDPC→lnIS		0.11848	0.8889
lnK→lnRGDPC	26	0.00618	0.9938
lnRGDPC→lnK		10.8126	0.0006
lnPOP→$lnRGDPC^2$	26	1.60686	0.2242
$lnRGDPC^2$→lnPOP		41.0269	0.0000
lnIS→$lnRGDPC^2$	26	0.30366	0.7413
$lnRGDPC^2$→lnIS		0.11731	0.8899
lnK→$lnRGDPC^2$	26	0.01970	0.9805
$lnRGDPC^2$→lnK		10.6702	0.0006
lnIS→lnPOP	26	1.33101	0.2856
lnPOP→lnIS		2.47188	0.1086
lnK→lnPOP	26	16.0170	0.0000
lnPOP→lnK		15.9180	0.0000
lnK→lnIS	26	0.85125	0.4411
lnIS→lnK		0.13191	0.8771

→indicates that variable "X" does not granger cause variable "Y"

5. Conclusion and policy implications

Environmental sustainability is a current global concern, increasing the debate on climate change mitigation and pollution reduction in recent decades. Several initiatives have been proposed namely a paradigm shift from fossil fuels to clean and renewable energy, and improved institutional quality. To this end, this study assessed the effect of renewable energy and institutional quality on environmental degradation in Somalia. To achieve the hypothesized relationship of the interested parameters, an ARDL bounds test, and Granger causality was adopted with time series data spanning 1990 to 2017. The empirical results demonstrate that renewable energy curtails environmental degradation by lowering deforestation whereas institutional quality enhances environmental quality in Somalia. In the same vein, gross fixed capital formation (domestic investment) undermines environmental degradation whereas an increase in population and economic growth impedes environmental quality. However, consistent with existing literature——the empirical results failed to validate the existence of EKC in Somalia. The findings of the Granger causality test reveal the presence of unidirectional causality from institutional quality to environmental degradation, from renewable energy to population, and from renewable energy to capital.

Climate change became one of the most widely discussed topics in the 21st century amid its negative consequences on the environment, growth, and livelihoods. Nevertheless, mitigating climate change and its impacts by reducing GHGs underpin the attention on clean energy production and consumption. Notably, the majority of least developed countries generate the largest share of energy from nonrenewable energy sources. For instance, 80%–90% of total energy consumption in Somalia is generated from firewood and charcoal [60]. This has calamitous effects on environmental quality [61]. As a result of this, Somalia encounters severe climate consequences repeatedly. The existing literature and this study showed renewables could decline environmental degradation. Investing in renewable energy sources – such as wind, solar, tidal power, geothermal, and wave should be the top priority of climate-vulnerable countries. Renewable energy sources are not only friendly for the environment but can lead to green growth. It is argued that a shift to green environment is indeed country-specific. Besides, strong government institutions play a constructive role in enhancing environmental sustainability. Institutional quality underpins political opportunism to enhance cooperative behavior among agents, making it possible for agents to internalize the externalities——which ultimately improves environmental quality. Our empirical findings have policy implications, hence, we propose a rapid shift from fossil fuels to clean and renewable energy. Renewables are friendly to environmental quality while promoting economic development. Additionally, enhancing institutional quality is critical for curbing environmental pollution. Hence, policymakers could implement policies to improve accountability, democracy (free and fair elections), and law & order.

CRediT authorship contribution statement

Abdimalik Ali Warsame: Conceptualization, Methodology, Formal analysis, Writing – original draft. **Ibrahim Abdukadir Sheik-Ali:** Writing literature and Improving the introduction. **Jama Mohamed:** Writing Introduction. **Samuel Asumadu Sarkodie:** Writing – review & editing.

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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