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The Significance of FDI Inflow and Renewable Energy Consumption in Mitigating Environmental Degradation in Somalia

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ABSTRACT

This study explores the impact of foreign direct investment (FDI), renewable energy, gross capital formation, population growth, gross domestic product (GDP), and the square of GDP on carbon dioxide (CO_2) emissions in Somalia between 1990 and 2019. To investigate the short-and long-run elasticity of environmental degradation and the other variables, autoregressive distributed lag (ARDL) model is employed. In Somalia, the long-run coefficients of the ARDL model indicate that renewable energy contributes negatively to environmental degradation. At the same time, domestic investment and population growth undermine the quality of the environment. Furthermore, the FMOLS results validate the existence of EKC in Somalia. The Granger causality test is also applied to investigate the causal relationship between the variables. Despite this, there was no evidence that FDI and renewable energy are causally related to environmental degradation. Based on our empirical assessment, the Somali government should encourage foreign direct investment, especially in technology-intensive and environmentally friendly industries, and pay increased attention to the improvement and consumption of renewable energy sources.

Keywords: Renewable Energy, FDI, FMOLS, ARDL, Somalia
JEL Classifications: P18, Q43, Q48

1. INTRODUCTION

Degradation of the environment is a worldwide issue that is gaining more and more attention from governments worldwide as a potential source of global warming and carbon cycle disruption. Climate change induced by greenhouse gas (GHGs) emissions is currently the most pressing issue confronting humanity, posing unprecedented challenges to growth and human survival, such as harsh weather, species extinction, and food scarcity (Dong et al., 2018). Carbon dioxide (CO_2) emissions are widely acknowledged to be the most significant contributor to modern climate change (Cai et al., 2018).

Over the past few years, economists have begun to seriously consider the environmental effects of economic growth. A large body of literature has developed in the recent decade on pollution's effect on income growth. Studies consistently find that environmental quality suffers at the beginning of economic development and growth but recovers later. That is to say; environmental pressure increases in tandem with GDP growth at higher income levels and decreases at lower income levels (Dinda, 2004). This demonstrates an inverted U-shaped relationship between per capita income and pollution, referred to as an environmental Kuznets curve (EKC) (Cole, 2004a). This inverted U-shaped relationship gets its name from the work of (Kuznets, 1955), which proposed a similar relationship between income inequality and economic growth. On the surface, the logic behind the EKC relationship seems tempting. A primary goal of the first stage of industrialization is to expand material output, as a result, people's priorities shift

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from protecting the environment to securing their financial futures (Dasgupta et al., 2002).

Pollutant emissions and other environmental woes, according to the EKC, disproportionately affect underdeveloped nations. It also means these nations face a conundrum when deciding which development project to accept, forcing them to pick between economic growth and environmental protection. They may have to put environmental protection on the back burner to fund economic growth and hope that the improved standard of living would fix any damage done to the natural world (Ibrahim and Law, 2014).

Foreign direct investment (FDI) has been on the rise for many emerging nations over the past two decades and is increasingly seen as a crucial tool for fostering economic growth and development (Zomorrodi and Zhou, 2017a). According to Bakhsh et al. (2017), FDI contributes into host economy via three folds: (i) FDI promotes the economic growth of the host economy (Alfaro et al., 2010). (ii) FDI is a form of international financing (Bustos, 2007). (iii) FDI decreases the gap between domestic savings and target investment (Ndikumana and Verick, 2008). Furthermore, FDI boosts economic activity by providing direct access to capital funding, creating positive externalities, transferring sophisticated technologies, enhancing productivity gains, and so forth (Shahbaz et al., 2015).

However, FDI can also bring environmental degradation. Two primary competing hypotheses regarding the nexus between FDI inflow and environmental degradation exist the pollution haven hypothesis (PHH) and the pollution halo hypothesis (Bildirici and Gokmenoglu, 2020).

The first, the pollution haven hypothesis, postulates that pollution-intensive production activities are directed from developed countries to those with laxer environmental regulations through FDI. This hypothesis suggests that for multinationals to evade costly environmental regulations in their country of origin, they relocate their polluting activities to less regulated countries (Mert and Caglar, 2020) (Copeland et al., 1994; Tobey, 1990). Hence, PHH states a positive relationship between FDI inflow and environmental degradation (Balsalobre-Lorente et al., 2019b). Second, the Pollution halo hypothesis states that FDI is presumed to reduce environmental deterioration by transferring environmentally friendly production methods from developed to developing countries and improving management in the host country (Shahbaz et al., 2016) (Azam et al., 2019). While the PHH holds that foreign direct investment (FDI) inflow is positively related to environmental pollution, the halo effect hypothesis holds the opposite stance (Doytch and Uctum, 2016).

A record high of $83 billion in foreign direct investment (FDI) was made in Africa in 2021, up from $39 billion the previous year. This amount represents 5.2% of global FDI. Following a dip in 2020 due to the pandemic, most recipients witnessed a slight increase in FDI in 2021. One South African intra-company financial transaction in the second half of 2021 inflated the continent-wide figure. Once that deal is taken out, the growth in Africa is moderate and in line with that of other developing regions. The flows to Southern Africa, East Africa, and West Africa all increased, whereas Central Africa experienced little change, and North Africa saw a decrease (UNCTAD, 2022).

Somalia has been ravaged by a 20-year-long civil war in which the society has suffered from a near-total absence of a functioning national state, a degraded natural environment, and frequent natural hazards (Thulstrup et al., 2020). Strong instability in the country continues to be a primary concern for international investors, which has hampered the country's FDI inflow.

Based on what we see in Figure 1, the inflow of FDI into the country has risen since 2012. FDI in the country peaked in 2020 at a whopping $464 million. Somalia's net FDI inflows grew from $1.7 million in 1971 to $464 million in 2020, with an average annual growth rate of 81.13%.

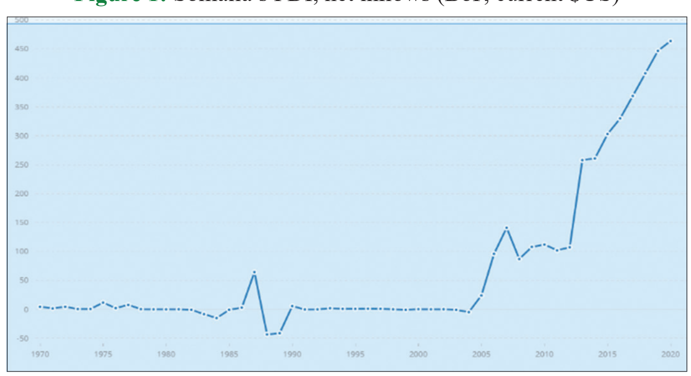
The current weak position of Al-Shabab and its losses are encouraging signs for investors. Turkish investment has fostered a development boom in Somalia's capital, Mogadishu, with some people feeling optimistic about the country's future. Food processing (especially bananas and fish) and the telecommunications industry have historically attracted the most considerable amounts of foreign direct investment (FDI) (LLYODS Bank, 2022). According to Ali et al. (2017), low foreign direct investment may deteriorate Somalia's financial growth, economic development, living standard, and gross domestic product.

Despite this, Somalia is presently undergoing energy shortage because most rural and urban households rely on traditional biomass (Warsame et al., 2022). Traditional biomass, such as firewood and charcoal, accounts for 82% of the country's total energy consumption; approximately 97% of urban households use charcoal, while rural households depend on firewood.

As a result, the forest resource is put under tremendous pressure, which speeds up desertification and hastens the devastation of pasture and agricultural land (UNEP, 2015).

Somalia is one of the world's least electrified countries. According to the World Bank (World Bank, n. d.), just 36% of the population has access to electricity, with only 11% living in rural regions. The country has a decentralized energy industry, which has evolved mainly in the lack of government and regulations. Each

Figure 1: Somalia's FDI, net inflows (BoP, current $US)



Source: World Bank

village electrifies its mini-grid through one of the dozens of small, hyperlocal private energy companies.

The Federal Government of Somalia reports that just approximately 10% of the country's electricity comes from renewable sources (Abdi Aynte, 2021). That is a pitiful amount considering the country's renewable energy potential. According to the African development bank (AfDB), as of 2021, Somalia has the most considerable resource potential of any African nation for onshore wind power. The country receives 3,000 h of sunlight annually, with daily solar radiation ranging from 5 to 7 kWh/m^2. This translates to solar solid photovoltaic electricity generation capacity. Wind power can generate up to 45,000 MW, and solar power can generate 2,000 MW (FGS and AfDB, 2015).

Renewable energy is an appealing choice for expanding new energy access to power in the country, and it is gaining support from both the public and the private sectors. Even though specific renewable-energy projects have been implemented successfully, the sector and the goals of a more significant transition to clean energy face severe obstacles due to the difficulty of obtaining traditional finance (Aynte et al., 2022).

Many studies have looked at the impact of FDI and renewables on environmental degradation (e.g., (Emre Caglar, 2020), (Doytch and Uctum, 2016), (Kisswani and Zaitouni, 2021), (Mert and Caglar, 2020), (Shahbaz et al., 2015), (Zomorrodi and Zhou, 2017b), (Cole, 2004b), (Muhammad et al., 2021), (Sabir et al., 2020), (Djellouli et al., 2022), among others). Unfortunately, as far as we know, no study has done an empirical analysis on the significance of FDI in combating environmental degradation in Somalia. On the other hand, (Warsame et al., 2022) investigated the role of institutional quality and renewable energy on environmental quality in Somalia. Nevertheless, they ignored the impact of FDI on the environment. Moreover, they employed deforestation as a measure of environmental degradation. The study will fill this gap by first using CO_2 emissions as a proxy for environmental degradation. Then it will analyze the significance of FDI inflows and renewable energy consumption in mitigating environmental degradation in Somalia.

The results of this research add two contributions to the existing body of knowledge: First, this research looks simultaneously at how foreign direct investment and renewable energy consumption might affect carbon dioxide emissions in Somalia. Second, CO_2 emissions are employed as an indicator of environmental degradation in the framework of the EKC to assess whether FDI affects carbon emissions in Somalia. Finally, reliable estimation methods based on fully modified ordinary least square (FMOLS) and ARDL are used to provide more extensive scheme suggestions from Somalia's EKC hypothesis. Section 2 reviews the relevant literature, Section 3 details the research approach and data, Section 4 dives into the findings and their discussion, and Section 5 offers a conclusion and policy implications.

2. LITERATURE REVIEW

The empirical studies investigating the interrelationships between FDI, renewable energy consumption and environmental degradation could be classified into two groups. The first group examines the relationship among FDI and environmental degradation. The second group examines the relation among renewable energy consumption and environmental degradation.

2.1. FDI-Environmental Degradation Nexus

Although FDI is undoubtedly a contributor to environment, the literature is divided on whether or not FDI helps to mitigate environmental degradation in the host country.

There are essentially two different schools of thought in the literary world. The Pollution Haven Hypothesis proposes that nations with stringent environmental policies desire to finance in nations with lax environmental policies so as to meet the demand for investment projects, even if this increases environmental degradation in the host country (Wagner and Timmins, 2009); (Balsalobre-Lorente et al., 2019a); (Solarin et al., 2017); (Millimet and Roy, 2016); (Cole and Elliott, 2005) and (Dietzenbacher and Mukhopadhyay, 2007). Whereas (Nguyen-Thanh et al., 2022); (Polloni-Silva et al., 2021); (Liobikienė and Butkus, 2019); (Repkine and Min, 2020) and (Sarkodie and Strezov, 2019) their findings align with the pollution halo hypothesis, which proposes that developing nations can recover from their environmental mismanagement and degradation thanks to foreign direct investment (FDI) in the form of improved management practices, cutting-edge technology transfers, and create environmental solutions.

Singhania and Saini, (2021) examined the relationship between FDI and sustainability for the period 1990-2016 using the data of 21 developed and emerging nations with high CO_2 emissions. As foreign direct investment (FDI) has a substantial positive impact on environmental degradation, the study uncovered evidence of pollution haven hypotheses, especially in developing nations. On the other hand, Kim and Adilov, (2011) used country-level data for 164 nations over 44 years to evaluate the veracity of both the pollution halo and pollution haven hypotheses. While lax environmental laws may entice foreign direct investment (FDI), the research showed that foreign enterprises operating in low-income nations use cleaner technology than their domestic counterparts. Thus, the foreign direct investment need not result in a rise in host countries' pollution levels. There are also a few other related papers listed in Table 1.

2.2. Renewable Energy and Environmental Degradation

A rising body of literature has examined the effect of renewable energy consumption on environmental quality at the national, regional, and global levels due to the fast-expanding deployment of renewable energy. For example, Employing ARDL method, (Warsame et al., 2022) investigated the effect of institutional quality and renewable energy on environmental degradation in Somalia for the period between 1990 and 2017. The empirical evidence showed that switching to renewable energy source reduces deforestation and thus helps to slow the rate of environmental deterioration.

(Dong et al., 2018) evaluated the communication among usage of renewable energy and CO_2 emissions for the time between 1965

Table 1: Literature review

Author	FDI leads toward environmental degradation in host country	FDI reduces environmental degradation in host country
(Muhammad et al., 2021)	√	
(Solarin and Al-Mulali, 2018)	√	
(Younis et al., 2021)	√	
(Shahbaz et al., 2018)	√	
(Adamu et al., 2019)	√	
(Dhrifi et al., 2019)		√
(Rafindadi et al., 2018)		√
(Hao and Liu, 2014)		√
(Hitam and Borhan, 2012)	√	
(Gorus and Aslan, 2019)	√	

and 2016 in China. Results showed that using natural gas and renewable energy improves environmental quality.

(Usman et al., 2020) evaluated the effect of renewable energy and trade policy on environmental quality in the United States between 1985Q1 and 2014Q4. The findings confirm that renewable energy consumption is beneficial for environmental quality.

Impact of trade and renewable energy consumption on environmental pollution in Turkey was the topic of research by (Karasoy and Akçay, 2018).The findings of the study showed that a rise in the renewable energy consumption decreases CO_2 emissions in equally the long-run and short-run. Likewise, (Koengkan, 2018) examined the effectiveness of Renewable energy consumption in reducing environmental degradation for selected five MERCOSUR's countries for the period 1980-2014. The empirical findings demonstrated a negative association between the consumption of Renewable energy and environmental degradation for the selected group of nations.

(Chien et al., 2021) studied the role of renewable energy in mitigating environmental degradation in Pakistan for the period between 1980 and 2018. The study's results showed that renewable energy sources have a negative impact on carbon dioxide emissions in Pakistan.

(Zandi and Haseeb, 2019) examined the impact of renewable energy in mitigating environmental degradation in the Sub-Saharan African countries over the period between 1995 and 2017. The study employed advanced panel data techniques such as bootstrap cointegration, CIP unit root test, FMOL, DOLS, and heterogeneous panel causality methods and Pedroni and Kao cointegration tests. The empirical findings concluded that green energy is environmentally favorable.

In Malaysia, (Ali et al., 2020) looked the correlation between renewable energy, and CO_2 emissions for the period 1971-2019. The study employed the wavelet tools to look into these interconnections. The findings revealed that there was a negative coherence among various frequencies of renewable energy and carbon dioxide.

(Balsalobre-Lorente et al., 2018) find out the determinants of CO_2 emissions in EU-5 countries for the period between 1985 and 2016. The empirical results demonstrated that renewable energy is one of the elements affecting CO_2 pollution by lowering CO_2 emissions and improving the quality of the environment. (Zoundi, 2017) examined the effects renewable energy consumption on CO_2 emissions in 25 African countries between 1980 and 2012. The research showed that renewable energy might be used as a replacement for traditional fossil fuels because of its negative impact on CO_2 emissions.

The relationship between environmental degradation, renewable and non-renewable energy usage, urbanization, and economic growth in 14 SSA nations from 1990 to 2014 were investigated by Wang et al. (Wang and Dong, 2019). The study concluded that encouraging the use of renewable energy sources could help reduce environmental degradation in SSA nations.

Using the STIRPAT model, (Shafiei and Salim, 2014) analysed the relationship between renewable and non-renewable energy consumption on CO_2 emissions in OECD nations for the period between 1980 and 2011. Their findings showed that using renewable energy reduces carbon dioxide emissions, while consumption of nonrenewable energy significantly increases carbon dioxide emissions.

Using panel data of 9 Mediterranean nations from 1980 to 2014, (Belaïd and Zrelli, 2019) created an empirical model to examine the causal link between renewable and non-renewable electricity consumption, GDP, and carbon emissions. The study found that renewable energy consumption decreases CO_2 emission, Therefore, increasing the use of renewable energy is a sensible way to deal with the challenges of energy security and to lessen the negative effects of carbon emissions on the environment for the benefit of future generations.

3. MATERIALS AND METHODS

3.1. Data

Data from 1990 to 2019 were used to construct a time series for analysis. Sampling observations are established by the set of data that are readily available. The data was obtained Freedom House, the Organization of Islamic Cooperation (OIC-SESRIC), and the World Bank. CO_2 emissions (a measure of environmental degradation), FDI, renewable energy, Real GDP per capita, population growth, and gross fixed capital formation are the variables used in this study (Table 2).

Table 2: Definition of variables

Variables	Code	Measurement	Sources
Environmental degradation	ED	CO_2 consumption emissions in millions of metric tons per capita	WB
Foreign direct investment	FDI	Net inflows (current $US)	WB
Renewable energy	RE	% of total final energy consumption	WB
Gross capital formation	K	In million of US$	SESRIC
Economic growth	RGDPC	Real gross domestic product per capita (constant 2015 $us)	SESRIC
Population growth	PG	Population growth (annual %)	WB

3.2. Econometric Methodology

The ARDL model was utilized in this study to achieve the outlined objective. In numerous aspects, ARDL bond testing outperforms conventional cointegration tests. This cointegration test can be employed regardless of whether the underlying variables are I (0), I (1), or a combination of the two (Pesaran et al., 2001). Second, ARDL tests, in general to specific modeling frameworks, capture the data generation process by allowing for a suitable number of lags. Third, in ARDL, short-run corrections can be integrated with a long-run equilibrium by deriving the error correction mechanism (ECM) via simple linear transformation without trailing long-run information. Fourth, because of its small sample features, the ARDL approach outperforms the Johansen and Juselius approach. In a multivariate model, the relationship between environmental degradation, FDI, Gross Capital Formation, renewable energy, population growth, economic growth, and the squared term of economic growth can be specified as follows:

$$InED_t = \beta_0 + \beta_1 InFDI_t + \beta_2 InK_t + \beta_3 InPG_t + \beta_4 InRE_t + \beta_5 InRGDPC_t + \beta_6 InRGDPC^2{}_t + \varepsilon_t \quad (1)$$

Where $\ln ED_t$ is the natural logarithm (ln) of environmental degradation, $InFDI_t$ is the natural logarithm of foreign direct investment, $\ln RE_t$ is the natural logarithm of renewable energy, InK_t is the natural logarithm of gross capital formation, $\ln RGDPC_t$ is the natural logarithm of Economic growth, $\ln RGDPC_t^2$ stands the natural logarithm of the squared term of economic growth, InPGt is the natural logarithm of population growth, and εt is the error term. All variables were log-transformed to avoid problems with non-normality, heteroskedasticity, and mis specified functional form. We employed the ARDL model to assess the short-and long-run cointegration between the explained and explanators. Based on the empirical findings of (Warsame and Sarkodie, 2021), the mathematical expression for ARDL cointegration can be written as follows:

$$\begin{aligned}\Delta InED_t &= \alpha_0 + \beta_1 InED_{t-1} + \beta_2 InFDI_{t-1} + \beta_3 InK_{t-1} \\ &+ \beta_4 InPG_{t-1} + \beta_5 InRE_{t-1} + \beta_6 InRGDPC_{t-1} \\ &+ \beta_7 RGDPC^2{}_{t-1} + \sum_{i=0}^{q} \Delta\alpha_1 InED_{t-k} \\ &+ \sum_{i=0}^{p} \Delta\alpha_2 InFDI_{t-k} + \sum_{i=0}^{p} \Delta\alpha_3 InK_{t-k} \\ &+ \sum_{i=0}^{p} \Delta\alpha_4 InPG_{t-k} + \sum_{i=o}^{p} \Delta\alpha_5 InRE_{t-k} \quad (2) \\ &+ \sum_{i=0}^{p} \Delta\alpha_6 InRGDPC_{t-k} + \sum_{i=0}^{p} \Delta\alpha_7 RGDPC^2{}_{t-k} + \varepsilon_{t-k}\end{aligned}$$

$$\begin{aligned}\Delta InED_t &= \alpha_0 + \beta_1 InED_{t-1} + \beta_2 InFDI_{t-1} + \beta_3 InK_{t-1} \\ &+ \beta_4 InPG_{t-1} + \beta_5 InRE_{t-1} + \beta_6 InRGDPC_{t-1} \\ &+ \beta_7 RGDPC^2{}_{t-1} + \sum_{i=0}^{q} \Delta\alpha_1 InED_{t-k} \\ &+ \sum_{i=0}^{p} \Delta\alpha_2 InFDI_{t-k} + \sum_{i=0}^{p} \Delta\alpha_3 InK_{t-k} \\ &+ \sum_{i=0}^{p} \Delta\alpha_4 InPG_{t-k} + \sum_{i=o}^{p} \Delta\alpha_5 InRE_{t-k} \\ &+ \sum_{i=0}^{p} \Delta\alpha_6 InRGDPC_{t-k} + \sum_{i=0}^{p} \Delta\alpha_7 RGDPC^2{}_{t-k} + \varepsilon_{t-k}\end{aligned}$$

Where α_0 is the constant, α_1-α_7 are the coefficients of the short-tun variables, β_1-β_7 are the long run elasticities of parameters, q indicates the explained's optimal lags, *p* demonstrates the optimal lags of the explanators, Δ is the sign of first difference showing short run variables and ε_t is the error term. The ARDL cointegration approach begins with bound testing.

The null hypothesis (H_0): $\beta_1 = \beta_2 = \beta_3 = \beta_4 = \beta_5 = \beta_6 = \beta_7 = \beta_8 = 0$ suggests that in the long-run variables are not cointegrated while the alternative hypothesis (H_1): $\beta_1 \neq \beta_2 \neq \beta_3 \neq \beta_4 \neq \beta_5 \neq \beta_6 \neq \beta_7 \neq \beta_8 \neq 0$ indicates that in the long-run variables are cointegrated. The critical values and Wald-F statistics were employed to assess the null hypothesis. If the Wald-F statistics exceed the upper bound critical values, the null hypothesis is rejected, indicating that the variables are linked in the long run and vice versa.

4. RESULTS AND DISCUSSION

4.1. Descriptive Analysis

Table 3 presents descriptive statistics for the data series to describe their characteristics. Findings show the mean of environmental degradation (−2.82), foreign direct investment (16.71), gross capital formation (19.5), population growth (0.80), renewable energy (4.53), and GDP (4.75). Furthermore, domestic investment and foreign direct investment have the greatest maximum values of (20.08) and (19.93), respectively. Except for environmental degradation and real GDP per capita, all variables are negatively skewed. FDI has the highest standard deviation (3.64), indicating that its normal values are far from its mean.

Based on the correlation test shown in Table 4, real GDP per capita is positively related to environmental degradation. Contrary to this, FDI, gross capital formation, population, and renewable energy consumption negatively correlate with environmental degradation.

Table 3: Descriptive statistics

Stats	InED	InFDI	InK	InPG	InRE	InRGDPC
Mean	−2.818317	16.71042	19.50334	0.796318	4.527952	4.746307
Median	−2.891066	16.66547	19.52885	1.026264	4.535499	4.672735
Maximum	−2.292270	19.92873	20.07505	1.333698	4.554193	5.218787
Minimum	−3.124114	0.000000	18.59452	−1.271585	4.468241	4.609561
Std. Dev.	0.244871	3.640450	0.348610	0.689237	0.023374	0.173649
Skewness	0.850960	−3.251562	−0.703680	−2.060171	−1.154831	1.907945
Jarque-bera	3.875248	263.0407	3.233674	33.47872	6.893877	23.84366
P-value	0.144046	0.000000	0.198526	0.000000	0.031843	0.000007

Table 4: Correlation

Variables	InED	InFDI	InK	InPG	InRE	InRGDPC
InED	1					
InFDI	−0.3486	1				
InK	−0.6087	0.0836	1			
InPG	−0.7452	0.0782	0.6991	1		
InRE	−0.9893	0.3188	0.6338	0.8765	1	
InRGDPC	0.8937	−0.1924	−0.6986	−0.7092	−0.9308	1

4.2. Unit Root Test

It is imperative to test unit root properties in time series modeling, particularly in ARDL. Therefore, we employed Philips Perron (PP) and Augmented Dickey-Fuller (ADF) tests to eliminate spurious regression outcomes. Test results show that the InFDI, InK, and InPG series are stationary at level [I (0)], while the other variables have a unit root. On the other hand, Table 5 shows that half of the series were stationary at the first difference [I (1)], and the other half were stationary at the first difference [I (0)]. Since no variables are stable at the second difference I (2), a cointegration test was performed using the bounds test.

A bounds test is presented in Table 6 to examine whether environmental degradation and regressors are cointegrated over time. However, at 5% significance level, Wald F-statistics (3.6672) exceeds the upper bound critical value (3.28). Hence, the variables are cointegrated in the long term.

4.3. ARDL Long-run and Short-run Results

The long-run estimations of the ARDL method are presented in Table 7, with some diagnostic test statistics. The results indicate that FDI has a negative effect on CO_2 emissions in Somalia, but it is statistically insignificant, implying that there is no long-term impact of FDI on the environment.

A positive and statistically significant relationship was also found between gross capital formation and CO_2 emissions. Consequently, a 1% increase in domestic investment leads to a 0.03% increase in environmental degradation. Furthermore, a positive correlation has been found between population growth and environmental degradation. Thus, a 1% increase in population growth contributes 0.07% to environmental degradation in the long run. In line with expectations, renewable energy consumption has a negative coefficient and is statistically significant. This indicates that a 1% increase in renewable energy consumption enhances environmental quality by 9.71% in the long run. Ultimately, this study found that real GDP per capita and its squared term are insignificant in the long run.

Table 5: Unit root test

Variable	T-statistics ADF	PP
InED	−2.1191	−1.5713
InFDI	−4.5896***	−4.5854***
InK	−3.5979**	−2.3384
InPG	−0.3054	−1.8930
InRE	−3.4186*	−2.9176
InRGDPC	−3.4664*	−2.5738
ΔInPG	−3.6882**	−3.0288*
ΔInED	−3.5991**	−3.6389**
ΔInRE	−3.8252**	−3.8387**
ΔInRGDPC	−5.6156***	−5.6063***

*, **,*** donate at 10%, 5%, and 1% significance levels. %. Δ shows I (1). The reported T-statistics are the intercept and trend

Table 6: F-bound test

F-statistic	Level of significance	Bounds test critical values	
		I (0)	I (1)
3.6672	1%	2.88	3.99
	5%	2.27	3.28
	10%	1.99	2.94

The results indicating that an increase in population growth leads to increased environmental degradation are in line with the findings of (Dong et al., 2018), (De Souza Mendonça et al., 2020), (Freedman, 2014), and (Wood and Garnett, 2009), who demonstrated that a growing population damages the environmental quality and accelerates anthropogenic global changes.

The findings showing the lessening impact of renewable energy are verified by several studies that discovered renewable energy can be adequate alternative for other fossil fuels, such as oil and coal, in the interest of decreasing CO_2 emissions. In studies like (Chen et al., 2019); (Noorpoor and Kudahi, 2015); and (Warsame et al., 2022) renewable energy has been shown to have a negative impact on CO_2 emissions and to play an essential role in mitigating them.

As a result of diagnostic checks, the ARDL model does not show heteroscedasticity, serial correlation, or normality problems and does not have any model misspecification. Additionally, CUSUM and CUSUM-square tests indicate that the coefficients of the ARDL model are stable over the sample period, as shown in Figures 2 and 3.

Based on the results of short-run estimations presented in Table 8, FDI is insignificant in the short run. In the short run, a negative statistically significant relationship exists between domestic investment and environmental quality. Therefore, a 1% increase in domestic investment decreases environmental degradation by 0.04%.

The effects of population growth and renewable energy consumption are similar in the short and long run. Therefore, a 1% increase in the growth of Somalia's populace will hamper environmental quality by 0.04%. Conversely, a 1% rise in renewable energy consumption leads to a 7.4% increase in environmental quality. Economic growth and its squared term significantly impact Somalia's environmental quality. A 1% increase in economic growth increases environmental quality by 8.45%, whereas the squared term of economic growth decreases it by 0.23% in the short term.

Further, Table 8 reveals the presence of a negative coefficient along with a statistically significant rate of adjustment (ECT). In other words, the ECT terms (i.e., −1.55) confirm that the variables are cointegrated over the long run. Therefore, the explanatory variables can adjust by 155% for the short-run shocks caused by environmental degradation.

4.4. Robust Analysis

Misspecified policy inferences might result from jumping to conclusions based on the results of a single approach. Due to this shortcoming, we used FMOLS to double-verify the ARDL long-run findings shown in Table 9. While variables like FDI, population growth, and gross capital accumulation all came out non-significant, the findings showed that variables like renewable energy consumption, GDP, and GDP squared had statistically significant effects on environmental quality in Somalia. We calculate a long-term improvement in the environmental quality

Figure 2: CUSUM test

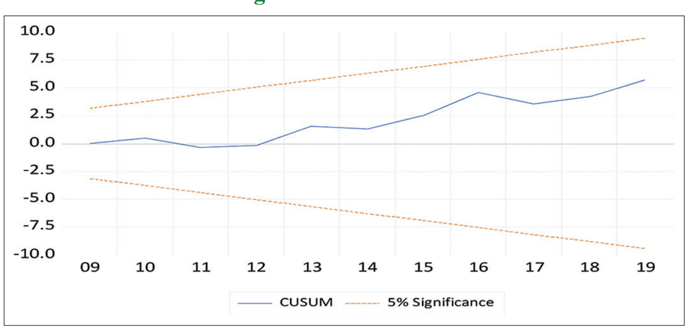


Figure 3: CUSUM square test

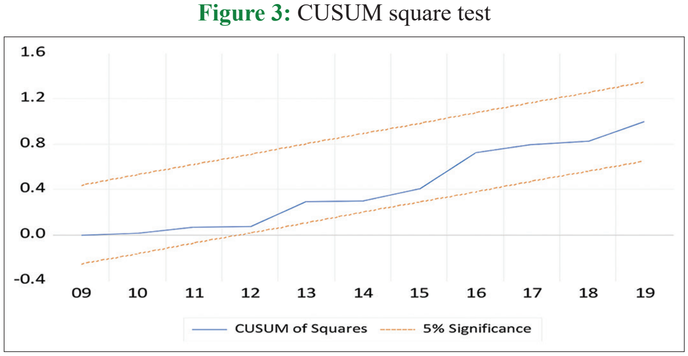


Table 7: Long-run results

Variables	Coefficient
C	37.4262
	(3.2554) ***
InFDI	–0.0012
	(–1.3501)
InK	0.0330
	(2.4290) **
InPG	0.0736
	(2.8167) **
InRE	–9.7051
	(–17.6503) ***
InRGDPC	0.7498
	(0.1613)
InRGDPC^2	–0.0056
	(–0.0489)
Reset test	2.1170 (0.1763)
Serial correlation	0.0137 (0.9070)
Heteroskedasticity	18.1373 (0.3159)
Normality	0.9491 (0.6222)

*, **,*** donate at 10%, 5%, and 1% significance levels. The T-statistics are cited in (.)

Table 8: Short-run and error correction results

Variables	Coefficient
ΔINED_{t-1}	0.7324
	(5.1773)***
ΔInFDI	–0.0006
	(–1.2090)
ΔInK	0.0159
	(1.6557)
ΔInK_{t-1}	–0.0434
	(–3.9141)***
ΔInPG	0.2139
	(5.9333)***
ΔInRE	–7.3998
	(–11.5321)***
ΔInRGDPC	–8.4494
	(–2.3774)**
$\Delta\text{InRGDPC}^2$	0.2252
	(–2.4968) **
ECT_{t-1}	–1.5548
	(–6.9287)***

Table 9: FMOLS method

Variable	Coefficient	t-statistic
InK	0.0141	1.1803
InPG	–0.0129	−1.2870
InRE	–10.1070***	−19.7767
InRGDPC	14.3321***	6.8024
InRGDPC2	–0.3653***	−6.9875
InFDI	–0.0009	−1.0083
C	7.6272	1.0638
R^2	0.9948	
Adjusted R^2	0.9934	
Mean dependent var	–2.8365	

of 10.11% for every 1% increase in the usage of renewable energy. Increasing GDP by 1% has a long-term negative impact on the environmental quality of 14.33%.

In contrast, increasing GDP squared by 1% has a long-term negative impact of 0.37% on the environmental degradation of Somalia. This substantiates the existence of the EKC hypothesis in the case of Somalia. Thus, The FMOLS findings corroborate the ARDL's findings in the long term.

4.5. Causality Test

In order to determine the direction of causality between variables, we conducted the Granger causality test shown in Table 10. From environmental degradation to population growth, domestic investment to population growth, domestic investment to GDP squared, and domestic investment to GDP, we observed unidirectional causation. There are bidirectional causal associations among population growth and economic growth and between the square of economic growth and population growth. In addition, there is evidence of a unidirectional causation between renewable energy and population growth.

Table 10: Granger causality tests

Null hypothesis	Obs	F-statitic	Prob.
InK→InED	28	0.92341	0.4114
InED→InK	28	0.57039	0.5731
InPG→InED	28	1.05885	0.3632
InED→InPG	28	2.71171	0.0876
InRE→InED	28	1.71917	0.2015
InED→InRE	28	0.30110	0.7429
InRGDPC→InED	28	1.38884	0.2695
InED→InRGDPC	28	0.47975	0.6250
InRGDPC^2→InED	28	1.37400	0.2731
InED→InRGDPC^2	28	0.43934	0.6498
InFDI→InED	28	0.01928	0.9809
InED→InFDI	28	1.08708	0.3539
InPG→InK	28	2.17415	0.1365
InK→InPG	28	6.89005	0.0045
InRE→InK	28	0.81569	0.4547
InK→InRE	28	1.16285	0.3303
InRGDPC→InK	28	1.71677	0.2019
InK→InRGDPC	28	5.02226	0.0155
InRGDPC^2→InK	28	1.71596	0.2020
InK→InRGDPC^2	28	4.99730	0.0158
InFDI→InK	28	0.43323	0.6536
InK→InFDI	28	0.58622	0.5645
InRE→InPG	28	3.86514	0.0357
InPG→InRE	28	0.26896	0.7665
InRGDPC→InPG	28	6.60561	0.0054
InPG→InRGDPC	28	6.12830	0.0074
InRGDPC^2→InPG	28	6.91533	0.0045
InPG→InRGDPC^2	28	6.27898	0.0067
InFDI→InPG	28	0.01207	0.9880
InPG→InFDI	28	0.03717	0.9636
InRGDPC→InRE	28	0.05567	0.9460
InRE→InRGDPC	28	0.70562	0.5042
InRGDPC^2→InRE	28	0.05627	0.9454
InRE→InRGDPC^2	28	0.63167	0.5407
InFDI→InRE	28	0.20642	0.8150
InRE→InFDI	28	0.88159	0.4277
InRGDPC^2→InRGDPC	28	0.51427	0.6046
InRGDPC→InRGDPC^2	28	0.52011	0.6013
InFDI→InRGDPC	28	0.03191	0.9686
InRGDPC→InFDI	28	0.25194	0.7794
InFDI→InRGDPC^2	28	0.02973	0.9707
InRGDPC^2→InFDI	28	0.24364	0.7858

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

5. CONCLUSION AND POLICY IMPLICATIONS

The present study employed ARDL bounds testing and the FMOLS model to examine the impact of foreign direct investment (FDI), domestic investment, population growth, renewable energy consumption, GDP, and GDP squared on CO_2 emissions over the period 1990-2019 in Somalia. In the long run, empirical results indicate that renewable energy reduces environmental degradation by reducing carbon dioxide emissions into the atmosphere. By contrast, gross fixed capital formation (domestic investment) and population growth are detrimental to environmental quality in the long run. Domestic investment, renewable energy consumption, and economic growth reduce environmental degradation in the short run. Contrary to this, the squared term of economic growth and population growth adversely affect the quality of the environment in Somalia. ECM's significant error coefficient confirms the existence of a long-run relationship between the variables.

Nevertheless, the empirical results from FMOLS confirmed the existence of EKC in Somalia. Moreover, our results are inconsistent with those of (Warsame et al., 2022), which do not support the validity of the EKC hypothesis in Somalia. These contradictory results for Somalia are likely due to differences in the econometric method used, the variables employed, and the datasets selected. The Granger causality test is also employed to determine whether the variables are causally related. Finally, the results indicate unidirectional causality between environmental degradation and population growth, as well as between renewable energy and population growth.

Several policy implications can be drawn based on empirical findings concerning environmental quality in Somalia. To begin with, Somalia should pay greater attention to the improvement and consumption of renewable energy, as well as provide financial, legal, and policy support to continue and promote the use of renewable energy. Furthermore, Somalia needs to increase the proportion of renewable energy in energy consumption and reduce the consumption of non-renewable energy. In addition, restrictive policies toward FDI inflows are unnecessary in Somalia since FDI does not significantly impact the environment, either over the short-or long term. As an alternative, Somalia ought to encourage FDI inflows to improve the quality of its environment, especially in technology-concentrated and environmentally friendly businesses, and observe the likely adverse environmental effects of pollution-intensive FDI inflows.

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