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Macroeconomic Pathways to Renewable Energy Expansion: Implications for Investment and Climate Policy

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ABSTRACT

The rising global demand for sustainable energy, driven by volatile fossil fuel prices and resource depletion, underscores the urgent need to understand the drivers of renewable energy adoption. This study empirically examines the macroeconomic determinants influencing renewable energy consumption in Somalia. Using national data from 1990 to 2022, the analysis employs the autoregressive distributed lag (ARDL) and dynamic least squares (DLS) approaches to estimate both short-run and long-run elasticities of key economic variables. The findings reveal that GDP has a positive but statistically insignificant effect on renewable energy use, with a 1% increase in GDP leading to a 0.021% rise in consumption over the long term. In contrast, foreign direct investment (FDI) and domestic investment exhibit negative effects, reducing renewable energy use by 0.002% and 0.046%, respectively. Trade openness is also negatively associated with renewable energy consumption (coefficient: −0.009), suggesting that greater trade liberalization may hinder renewable energy adoption. Conversely, population growth positively influences renewable energy use, while carbon emissions show a negative relationship, emphasizing the importance of tailored energy strategies aligned with national economic conditions. Based on these findings, the study recommends that the Somali government establish a comprehensive renewable energy policy framework, revise trade policies to support clean energy goals, incentivize green FDI, and strengthen regulatory institutions to foster sustainable energy investment.

Keywords: Climate Change, Renewable Energy, Trade Openness, Foreign Direct Investment, Carbon Emissions, Autoregressive Distributed Lag
JEL Classifications: E0, Q2, Q4

1. INTRODUCTION

Renewable energy is a non-fossil, carbon-neutral, and clean energy source that has evolved through advanced technology. It differs significantly from traditional fossil fuels in terms of theoretical technology, cost of use, environmental impact, and management strategies. The renewable energy sector is currently experiencing a breakthrough phase due to new materials, artificial intelligence, Internet Plus, and renewable energy technologies (Zhang et al., 2021). The global demand for sustainable energy is increasing due to volatile fossil fuel prices and depleting resources. Alternatives include reducing dependence on imported fossil fuels and utilizing domestic renewable energy sources like hydropower, solar, wind, geothermal, tidal, and waste-to-energy. These sources generate more positive externalities and support the development of both developed and developing countries (Qamruzzaman et al., 2022). Specially, emerging nations' energy needs are rising due to factors like urbanization, industrialization, population growth, technological advancement, and a sharp rise in trade (Zeren and Akkuş, 2020).

The Intergovernmental panel on climate change (IPCC) and the international monetary fund (IMF) have both highlighted the need for significant changes in energy, land, urban infrastructure, and industrial systems to limit global warming (Akan, 2023). Regardless of these global initiatives, energy consumption remains an essential element in recent economies, driving socio-economic advancement in developed nations. According to (Usman et al., 2021), energy is essential for everyday tasks, family needs, social mobility, and combating poverty and hunger.

However, to lessen environmental harm, renewable energy comes from natural sources (Adams and Acheampong, 2019). Development goals and strategies are crucial for guiding energy transition approaches that align with sustainable climate targets. The transition to a low-carbon energy system aims to address economic vulnerabilities and climate risks, with energy system modelling aiding in capacity expansion at national, regional, and global levels (Ullah et al., 2024).

In Sub-Saharan Africa (SSA), energy supply faces numerous challenges, including physical scarcity, geopolitical barriers to access, high costs that reduce affordability, environmental concerns affecting social acceptance, and limitations in infrastructure and scalability. Additionally, the region remains highly vulnerable to external shocks, such as fluctuations in global energy prices, which are quickly transmitted and disrupt local energy stability (Adedeji et al., 2024). Consequently, SSA has one of the lowest per capita electricity consumption rates globally, reflecting widespread electricity inaccessibility amid rapid population growth. While a few countries still rely on fossil fuels, the majority of SSA nations depend on renewable sources driven by persistent fossil fuel subsidies, weak regulatory institutions, and heightened macroeconomic risks (Olanrele and Fuinhas, 2022).

Africa overall has the lowest energy access worldwide, with 43% of its population lacking electricity. Somalia, despite having substantial renewable potential including the highest onshore wind capacity in the region, 3,000 h of annual sunshine, and 5–7 kWh/m^2 of daily solar radiation still faces severe energy access challenges. Only 36% of the Somali population has electricity access, largely due to a decentralized energy sector, weak regulatory frameworks, and inefficient administrative oversight (Warsame, 2022; Warsame et al., 2024). Conversely, the widespread adoption of renewable energy not only offers environmental benefits but also provides substantial economic gains. Electricity generated from natural renewable sources can positively influence key development indicators such as GDP, employment levels, and trade balances (Andini et al., 2019).

This study aims to empirically investigate the macroeconomic determinants influencing renewable energy use in Somalia, focusing on variables such as GDP, foreign direct investment (FDI), domestic investment (DI), trade openness, population growth, and carbon emissions. Thus, the study employs ARDL approach on national data, to determine both the short-run and long-run elasticities of these factors and provide policy-relevant insights for sustainable energy planning in Somalia.

While numerous studies have examined the nexus between macroeconomic variables and renewable energy across various regions including Pakistan (Iqbal et al., 2023), Malaysia (Mohamed Yusoff et al., 2023), Nigeria (Foye, 2023), and Sub-Saharan Africa at large (Riti et al., 2022) very limited empirical research has addressed this relationship in the context of Somalia. Previous Somali-based studies e.g., (Nor and Hassan Mohamud, 2024; Warsame et al., 2023), have primarily explored the effect of renewable energy on environmental and economic outcomes, often overlooking the macroeconomic determinants that directly shape renewable energy production itself. Moreover, the role of asymmetric effects and nonlinear linkages, critical in emerging economies, remains underexplored in the Somali context.

This study makes a novel contribution by providing the ARDL-based empirical analysis of the macroeconomic determinants of renewable energy production in Somalia. Unlike prior research that focused on the impact of renewable energy on economic or environmental outcomes, this study reverses the perspective by identifying how GDP, FDI, DI, trade openness, population growth, and carbon emissions influence renewable energy use. The findings reveal that while GDP and population growth positively drive renewable energy consumption, FDI, DI, and trade openness have adverse effects highlighting a misalignment between current investment flows and sustainable energy goals. These insights offer valuable guidance for policymakers to redirect macroeconomic levers and investment strategies toward fostering a more sustainable and inclusive energy transition in Somalia.

The rest of the paper is structured as follows. Section Two focuses on the "Review of Related Literature," providing a comprehensive overview of existing body scholarly works. In section Three, "Methodology," the study elaborates on its data collection methods, and empirical approach. Section Four "Empirical Results and Discussion," presents and analyzes the gathered data. Finally, section Five, "Conclusions and Policy Implications" summarizes key findings, discusses implications, and suggests potential areas for future research.

2. LITERATURE REVIEW

Sub-Saharan Africa has significant renewable energy resources that could significantly impact its development. However, the region has been historically overlooked by energy investors, leading to underutilization of these resources. Factors contributing to this underutilization include low savings rates, poorly developed financial markets, low demand, high transmission losses, limited power generation planning, corruption, under-pricing, financial weakness of electric utilities, and a lack of technological knowledge. These issues hinder Africa's ability to harness its renewable energy potential effectively (Pueyo, 2018).

In Malaysia, Mohamed Yusoff et al. (2023) analyzed macroeconomic determinants of renewable energy adoption. Their long-term results show that economic development and urbanization positively influence renewable energy use, whereas increased foreign direct investment (FDI), trade liberalization, and carbon emissions negatively impact its utilization. Similarly, Foye (2023) investigated Nigeria using the autoregressive distributed lag (ARDL) method on data from 1990 to 2020 and concluded that macroeconomic variables play a critical role in shaping renewable energy penetration.

Bekun and Alola, (2022) found that a 1% increase in economic activity raises renewable energy consumption by 0.128% in the short term. However, in the long run, economic growth reduces renewable energy use by 0.402%, suggesting a complex dynamic over time. Meanwhile, Riti et al. (2022) concluded that renewable energy and capital formation significantly enhance long-term economic growth in SSA. However, while GDP and capital investment increase GHG emissions, renewable energy contributes to their reduction, making it crucial for balancing economic and environmental sustainability.

Iqbal et al. (2023), using both symmetric and asymmetric ARDL models in Pakistan, found that positive changes in GDP, CO_2 emissions, and financial development significantly enhance renewable energy production in the long term, while negative changes are insignificant. GDP emerged as the only consistent long-term driver. Khan and Gunwant (2024) found that remittance inflows slightly reduce renewable electricity production, whereas literacy rates positively influence it. In contrast, government spending, urbanization, and energy imports negatively affect renewable energy output.

Qamruzzaman et al. (2022) examined economic policy uncertainty (EPU), FDI, and government debt in oil-importing countries from 1995 to 2018. Their results reveal that EPU negatively affects renewable energy use, while FDI and debt have positive effects. Similarly, Zhang et al. (2021) assessed trade openness in 35 OECD countries and found a nonlinear relationship: import levels above 40.945% of GDP may inhibit renewable energy use, while trade and exports support it. Wang and Zhang (2021) further noted that trade openness positively affects renewable energy in high- and upper-middle-income countries but negatively in lower-middle-income nations.

Ebaidalla (2024) studied the role of taxation, innovation, and trade openness in 37 leading renewable energy-producing countries. Taxation was found to hinder renewable energy investment, while innovation and trade openness encouraged it. However, tax revenues diminished the positive effects of innovation and trade.

Murshed (2018) found that increased trade openness enhances access to clean cooking fuel, energy-use efficiency, and renewable energy adoption. Han et al. (2021) observed that trade boosts non-renewable energy use while only partially improving green energy use, reflecting the dominance of fossil fuels in production and exports.

Wei et al. (2022) confirmed that renewable energy significantly reduces GHG emissions, with FDI playing a favorable long-term role. Dossou et al., (2023) also reported that FDI positively affects renewable energy adoption and that governance quality is strongly associated with its consumption. Noah and Olalekan (2025) highlighted the influence of external funding on energy development in SSA, finding that official development assistance hampers progress, while FDI and private sector participation foster long-term growth.

Kang et al. (2021) studied South Asian countries and found a negative relationship between FDI and renewable energy, but a strong positive link between GDP and renewable energy use. Doytch and Narayan (2016) showed that FDI can reduce non-renewable energy consumption and increase renewable energy use, with variations depending on the sector receiving investment.

Lyeonov et al. (2019) examined the 2008–2016 financial crisis in the EU and found that GDP per capita, GHG emissions, renewable energy, and green investments were interlinked, with GDP strongly influencing green investment trends. Demographic factors also play a role. Salim and Shafiei, (2014) concluded that while urbanization and overall population growth promote renewable energy use, population density reduces non-renewable energy consumption. Su et al. (2022), using data from 116 countries, found a nonlinear relationship between socio-economic factors and renewable energy use, where urbanization increased consumption, but industrialization hindered it.

Fang et al. (2022) explored the effect of urbanization and education on energy demand in emerging economies. They found that while income and education influence energy use, urbanization and globalization tend to decrease demand for both renewable and non-renewable sources. Industrialization, however, raises energy demand without reducing fossil fuel reliance.

Kwilinski et al. (2023) reported that sustainable economic development declined in 2020 due to urbanization, although green growth was supported by structural reforms and technological advancement. Yang et al. (2016a) found that demographic, economic, and energy mix factors promote renewable energy use, though energy intensity has a negative effect. The impact of urbanization was found to be more significant for overall energy use than for renewable energy alone.

Lastly, Akintande et al. (2020) assessed five of Africa's most populous nations and identified population growth, urbanization, energy use, electric power consumption, and human capital as major drivers of renewable energy use. Dong et al. (2018) found that globally and regionally, economic growth and population size significantly affect CO_2 emissions, while increasing renewable energy intensity reduces them, particularly in South and Central America and Europe.

3. MATERIALS AND METHODS

3.1. Data

This study utilizes secondary data from the World Bank and SESRIC covering the period from 1990 to 2022 to empirically investigate the macroeconomic determinants of renewable energy use in Somalia. Specifically, it examines the influence of key variables such as gross domestic product (GDP), foreign direct investment (FDI), domestic investment (DI), trade openness, population growth, and carbon emissions (Table 1). The dependent variable in the analysis is renewable energy consumption, measured as a percentage of final energy consumption.

3.2. Econometric Methodology

In this study, we utilized an ARDL model to achieve our outlined objectives. The ARDL bond testing method, chosen for its superior performance over conventional cointegration tests, offers flexibility in handling variables with different integration levels. In addition, the ARDL bounds testing method provides various advantages over alternative cointegration tests. Despite its smaller sample size, it exhibits greater resilience to changes in the order of variable

Table 1: Description of the variables

Variable	Code	Measurement	Source
Renewable energy use	RE	% of final energy consumption	WB
Economic growth	GDP	GDPC (constant 2015 $US)	WB
Foreign direct investment	FDI	Net inflows (BoP, current US$)	WB
Trade openness	TO	Trade % of GDP	SESRIC
Domestic investment	DI	Gross fixed capital formation (% of GDP)	WB
Population growth	POP	Total Population	WB
Carbon emissions	CO_2	Carbon emissions excluding LULUCF per capita (t CO_2e/capita)	WB

integration, yielding objective estimates and reliable statistics. Moreover, it accounts for the occurrence of temporal structural breakdowns. This approach incorporates GDP and foreign direct investment, as well as Domestic investment, Trade openness, population growth, and carbon emissions, as control variables. Based on the estimated variables the functional form of the model can be as follows:

$$RE = f(GDP, FDI, TO, DI, POP, Co2) \tag{1}$$

Where:
RE_t represents renewable energy
GDP_t represents economic growth
FDI_t represents foreign direct investment
DI_t represents domestic investment.
TO_t represents trade openness
POP_t represents population growth
CO_{2t} represents carbon emission.

The variables from the initial functional form in Equation 1 have been converted into log-linear forms (LN). This log version provides insights into both short-term and long-term elasticity. Transforming all variables into logarithmic form aims to improve reliability and mitigate issues such as non-normality, heteroskedasticity, and mis-specified functional forms. This transformation follows the method outlined by (Shahbaz et al., 2010).

$$lnRE_t = \beta_0 + \beta_1\, lnGDP_t + \beta_2\, lnFDI_t + \beta_3\, lnTO_t + \beta_4\, lnDI_t + \beta_5\, lnPOP_t + \beta_6\, lnCO_{2t} \tag{2}$$

According to the empirical results from Warsame and Sarkodie (2021), the mathematical expression the ARDL model, derived from the Unrestricted Error Correction Model (UECM), is presented below:

$$\begin{aligned} lnRE_t &= \alpha_0 + \partial_1 lnGDP_{t-1} + \partial_2 lnFDI_{t-1} + \partial_3 lnTO_{t-1} \\ &\quad + \partial_4 lnDI_{t-1} + \partial_5 lnPOP_{t-1} + \partial_6 lnCO2_t \\ &\quad + \sum_{i=0}^{\rho} \Delta\alpha_2 lnGDP_{t-k} + \sum_{i=0}^{q} \Delta\alpha_3 lnFDI_{t-k} + \sum_{i=0}^{q} \Delta\alpha_4 lnTO_{t-k} \\ &\quad + \sum_{i=0}^{q} \Delta\alpha_5 lnDI_{t-k} + \sum_{i=0}^{q} \Delta\alpha_6 lnPOP_{t-k} + \sum_{i=0}^{q} \Delta\alpha_7 lnCO2_{t-k} + \varepsilon_{t-k} \end{aligned} \tag{3}$$

Δ is the sign of the first difference showing short-run variables and εt is the error term. While ∂ coefficients depict the long-run elasticities of the variables.

ARDL starts with testing the null hypothesis of joint cointegration using the bound test: The null hypothesis H_0: There is no relationship H_0: $\beta_1 = \beta_2 = \beta_3 = \beta_4 = \beta_5 = \beta_6 = 0$

The alternative hypothesis H_A: There is relationship H_A: $\beta_1 \neq \beta_2 \neq \beta_3 \neq \beta_4 \neq \beta_5 \neq \beta_6 \neq 0$.

Where α_0 is the constant, α1-α7 are the coefficients of the short-tun variables, ∂ 1-∂ 7 are the long- run elasticities of parameters, q indicates the explanators' optimal lags, p demonstrates the optimal lags of the explained variable, Δ is the sign of first difference showing short run variables and εt is the error term.

We also estimate the error correction to measure the rate at which the long-term equilibrium level path is adjusted, the ECM equation can be expressed as:

$$\begin{aligned} \Delta InRE_t &= \alpha_0 + \sum_{i=0}^{p} \Delta\alpha_1 InRE_{t-k} + \sum_{i=0}^{q} \Delta\alpha_2 InGDP_{t-k} \\ &\quad + \sum_{i=0}^{q} \Delta\alpha_3 InFDI_{t-k} + \sum_{i=0}^{q} \Delta\alpha_4 InTO_{t-k} + \sum_{i=o}^{q} \Delta\alpha_5 InDI_{t-k} \\ &\quad + \sum_{i=0}^{q} \Delta\alpha_6 InPOP_{t-k} + \sum_{i=0}^{q} \Delta\alpha_7 InCO2_{t-k} + \Delta ECT_t + \varepsilon \end{aligned} \tag{4}$$

4. RESULTS AND DISCUSSION

4.1. Unit Root Test

The outcomes of the augmented Dickey-fuller (ADF) and Phillips-Perron (PP) unit root tests are displayed in Table 2, offering key insights into the stationarity characteristics of the model's variables. The analysis was conducted across four specifications: Intercept only, intercept with trend, at level, and at first difference. Under the intercept specification, variables such as LNGDP, LNFDI, LNTO, and LNDI were found to be non-stationary at level, indicating the presence of unit roots. Conversely, LNRE and $LNCO_2$ were stationary at level, suggesting no unit root. Upon applying first differencing, all variables achieved stationarity, confirming the removal of unit roots. Furthermore, under the intercept and trend specification, all variables LNGDP, LNFDI, LNTO, LNDI, LNPOP, LNRE, and $LNCO_2$—were stationary at first difference. These findings validate the use of the ARDL (Autoregressive Distributed Lag) model for analyzing the long-term effects of macroeconomic indicators on renewable energy.

4.2. Cointegration Analysis

Table 3 presents the results of the bounds test for cointegration among the study variables. The analysis revealed a significant cointegrating relationship at the 1% level between LNRE, LNGDP, LNFDI, LNTO, LNDI, LNPOP, and $LNCO_2$. The computed F-statistic of 7.007852 exceeded the upper-bound critical value of 4.43 at the 1% significance threshold, confirming a long-term association among the variables. This outcome supports the appropriateness of the ARDL framework for modelling the long-run dynamics of renewable energy determinants.

4.3. ARDL Short Run and Long Run Result Analysis

Table 5 summarizes the long-run coefficient estimates. GDP (LNGDP) was found to exert a positive and statistically insignificant influence on renewable energy (LNRE), with a coefficient of 0.021. This indicates that a 1% increase in GDP leads to a 0.021% increase in renewable energy consumption over the long term. These findings align with previous studies by (Chica-Olmo et al., 2020; Kocsis and Kiss, 2015; Lyeonov et al., 2019), reaffirming the crucial role of economic growth in fostering renewable energy adoption by boosting energy demand and supporting technological advancement.

In contrast, foreign direct investment (LNFDI) showed a negative impact on renewable energy, with a statistically significant coefficient of −0.002 at the 1% level. This suggests that a 1% increase in FDI results in a 0.002% decline in renewable energy usage, consistent with results reported by (Kang et al., 2021). The findings imply that current FDI patterns may not be directed toward green investments due to a preference for traditional energy sources, lack of financial or technological incentives, and inadequate infrastructure (Mohamed Yusoff et al., 2023). On the other hand, domestic investment (LNDI) also negatively influenced renewable energy use, with a long-run coefficient of −0.046, statistically significant at the 1% level. A 1% rise in domestic investment corresponds to a 0.046% decrease in renewable energy output, contradicting the positive long-run relationship found by (Afumbom et al., 2020). These results emphasize the necessity of a supportive economic environment and effective regulatory mechanisms to enhance the effectiveness of DI and FDI in accelerating energy transitions.

Trade openness (LNTO) was also negatively associated with renewable energy consumption, with a long-run coefficient of −0.009, significant at the 5% level. This implies that increased trade openness may inadvertently reduce the adoption of renewable energy in Somalia. Trade liberalization might shift focus toward economic gains at the expense of sustainable energy goals, especially if technological capacity and policy alignment are lacking.

Population growth (LNPOP), on the other hand, positively influenced renewable energy consumption, with a coefficient of 0.177, statistically significant at the 1% level. This is consistent with findings by Akintande et al. (2020) and Yang et al. (2016b), suggesting that higher population levels drive increased energy demand, including renewables.

Carbon emissions ($LNCO_2$) exhibited a negative and statistically significant relationship with renewable energy consumption, with a long-term coefficient of −0.058. This contradicts Nguyen and Kakinaka (2019), who found a positive correlation between renewable energy and carbon emissions in low-income countries. The divergence in findings underscores the need for country-specific renewable energy strategies based on economic status. Notably, carbon pricing has been shown to promote renewable energy development in recent work by (Xu and Yang, 2024).

For the Short-run estimations from the ARDL model, also shown in Table 5, revealed that all variables such as FDI, trade openness, domestic investment, population growth, and carbon emissions, (except GDP) had statistically significant short-run effects on renewable energy. GDP did not show a notable impact in the short term. These findings enhance the understanding of short-run dynamics and provide valuable input for policymakers aiming to promote renewable energy consumption in Somalia.

The error correction term (ECT) coefficient was −0.897825, confirming a strong and statistically significant convergence toward long-run equilibrium. The large negative value indicates that deviations from the long-run path are corrected rapidly.

Table 2: Unit root test

Variable	ADF unit root test			
	Intercept		Intercept+Trend	
	Level	1st difference	Level	1st difference
LNRE	−6.3077***	−3.821799***	−5.109820***	−4.175917**
LNGDP	0.068082	−4.655272***	−2.181236	−4.865095***
LFDI	−0.950593	−6.713922***	−3.365663*	−6.532483***
LNTO	−1.470734	−2.114284	−1.795539	−2.088323
LNDI	2.700764	−1.609748	−1.702628	−5.681042***
LNPOP	−1.470716	−2.141152	−3.709330**	−2.181784
LNCO2	−2.486635	−4.910310***	−2.393465	−4.721820***
Variable	**PP unit root test**			
	Intercept		**Intercept+Trend**	
	Level	**1st difference**	**Level**	**1st difference**
LNRE	−5.912137***	−3.819135***	−5.149112***	4.142293**
LNGDP	−0.168443	−4.791675***	−2.186795	−4.967839***
LNFDI	−0.806281	−6.995455***	−3.482774	−6.789624***
LNTO	−0.998289	−7.631844***	−1.272694	−10.54673***
LNDI	2.239705	−3.556420**	−2.070610	−5.691089***
LNPOP	0.974824	−4.616015***	−3.939097**	−4.192857***
LNCO2	−2.775274*	−4.929803***	−2.732813	−4.744673***

***, **, and * refer to the significance level at 1%, 5% and 10% respectively.

Table 3: Detecting the presence of long-run cointegration based on F stat

Model	Lag order	F-statistics
RE=f (GDP, FDI, TO, DI, POP, CO_2)	(1,1,2,1,1,2,2)	7.007852
Critical value for F statistics	Lower I (0)	Upper I (1)
10%	2.12	3.23
5%	2.45	3.61
1%	3.15	4.43

Table 4: Diagnostic test

Diagnostic test	F-statistics	Prob.
Breusch-Godfrey serial correlation	2.621352	0.1136
Heteroskedasticity	0.480248	0.9195
Jarque-Bera normality test	1.565302	0.457192

Table 5: Short run and long run elasticity

Variable	Coefficient
D (LNGDPC)	−0.00519
D (LNFDI)	−0.00079**
D (LNTO)	−0.01974***
D (LNDI)	−0.02016***
D (LNPOP)	−0.11480***
D ($LNCO_2$)	0.030854***
CoinEq(−1)*	−0.897825***
Long run	
LNGDP	0.021069
LNFDI	−0.002304***
LNTO	−0.009570**
LNDI	−0.046994***
LNPOP	0.177355***
$LNCO_2$	−0.058286***

***, **, and * refer to the significance level at 1%, 5% and 10% respectively

Table 6: Dynamic least square

Variable	Coefficient
LNGDPC	0.072881**
LNFDI	−0.002008***
LNTRO	−0.025401**
LNDI	−0.071747**
LNPOP	0.239548***
$LNCO_2$	−0.068876***

***, **, and * refer to the significance level at 1%, 5% and 10% respectively

Figure 1: Cumulative sum

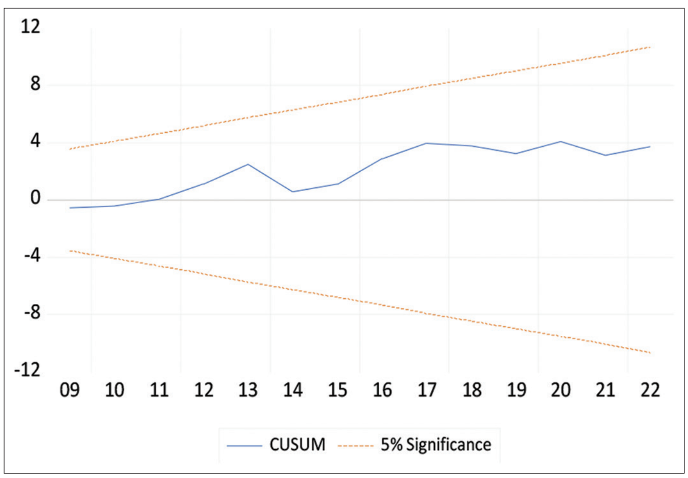
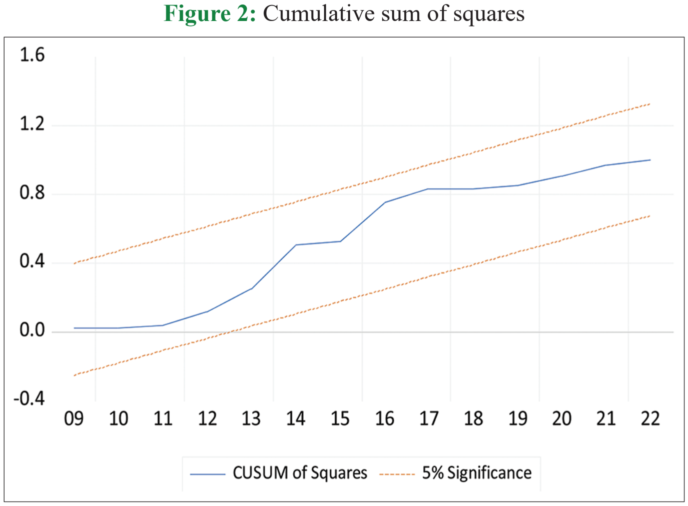


Figure 2: Cumulative sum of squares



Diagnostic tests including Jarque-Bera for normality, Breusch-Godfrey for serial correlation, and heteroskedasticity, are summarized in Table 4. All tests produced P > 10%, indicating no violations of classical regression assumptions. This confirms the reliability and robustness of the model.

Finally, Figures 1 and 2 present the stability analysis results using CUSUM and CUSUM of Squares. Both graphs remained within the critical bounds, confirming that the model is structurally stable at the 5% significance level.

4.4. Robustness Analysis

Relying on a single estimation technique may lead to ambiguity in drawing policy conclusions and formulating recommendations. To avoid potential misinterpretations, this study cross-validated the long-run results obtained from the autoregressive distributed lag (ARDL) model by employing the dynamic least squares (DLS) method. The DLS approach was used to confirm the robustness of the ARDL findings and to ensure that policy implications were not based on potentially biased outcomes from a single methodology. As shown in Table 6, GDP maintained a statistically significant impact on renewable energy consumption in Somalia, consistent with the ARDL long-run results, though the level of significance differed slightly indicating a 5% significance level under DLS. These results align with prior long-term evaluations, thereby reinforcing the validity and reliability of the ARDL model's long-run estimates.

5. CONCLUSION AND POLICY RECOMMENDATIONS

Renewable energy is a non-fossil, carbon-neutral, and clean energy source that is gaining momentum due to advancements in technology, artificial intelligence, and internet plus. The global demand for sustainable energy is increasing due to volatile fossil fuel prices and depleting resources. Alternatives include reducing dependence on imported fossil fuels and using domestic renewable energy sources like hydropower, solar, wind, geothermal, tidal, and waste-to-energy. Emerging nations' energy needs are rising due to factors like urbanization, industrialization, population growth, technological advancement, and trade. So, this study aims to empirically investigate the macroeconomic determinants influencing renewable energy use in Somalia, focusing on variables such as GDP, foreign direct investment (FDI), domestic investment (DI), trade openness, population growth, and carbon emissions. To do so, the ARDL approach employed on national data, to determine both the short-run and long-run elasticities of these factors and provide policy-relevant insights for sustainable energy planning in Somalia.

The study found that GDP has a positive and insignificant impact on renewable energy consumption, with a 1% increase in GDP leading to a 0.021% increase in consumption over the long term. However, foreign direct investment (FDI) has a negative impact, with a 0.002% decline in renewable energy usage. Domestic investment also negatively influences renewable energy use, with a long-run coefficient of −0.046. Trade openness negatively affects renewable energy consumption, with a long-run coefficient of −0.009, suggesting that increased trade liberalization may reduce renewable energy adoption. Population growth positively influences renewable energy consumption, while carbon emissions have a negative relationship with renewable energy consumption, highlighting the need for country-specific renewable energy strategies based on economic status.

Based on the study's findings, several policy recommendations are proposed to support renewable energy development in Somalia. First, the government should prioritize the establishment of a comprehensive and coherent policy framework that encourages both domestic and foreign investment in the renewable energy sector. This includes implementing clear incentives and regulatory measures to foster sector growth. Second, since the findings indicate that trade openness negatively affects renewable energy expansion, trade policies should be carefully revised to ensure they align with clean energy goals and do not impede sectoral progress. Third, promoting green foreign direct investment (FDI) is crucial; targeted incentives should be introduced to attract public and private participation in renewable energy projects. Creating favorable macroeconomic conditions and a policy environment that supports technological innovation is essential for this transition. Lastly, the study underscores that a weak regulatory framework can deter investment and hinder project execution. Therefore, strengthening legal and institutional structures is vital to establishing a stable, transparent, and supportive environment for sustainable energy investment.

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