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Abdimalik Ali Warsame[1,*], **Ibrahim Abdukadir Sheik-Ali**[1], **Hassan Abdikadir Hussein**[2] and **Galad Mohamed Barre**[2]

[1] Faculty of Economics, SIMAD University, Somalia
[2] Faculty of Management Science, SIMAD University, Somalia
[*] Author to whom any correspondence should be addressed.

E-mail: abdimalikali1995@gmail.com

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Abstract

Climate change is considered one of the most defining challenges in this century because it poses a threat to the health and well-being of every person in the world by posing a large aggregate risk to the economy. Developing and least developed countries such as Somalia are the most vulnerable countries to climate change consequences. Besides the vulnerability to climate change, government institutions in Somalia have been malfunctioning since 1991 hence affecting economic growth. Hence, this empirical work addresses the long-and short-run effects of institutional quality and climate change on economic growth in Somalia for the period 1985–2017 using the autoregressive distributed lag model (ARDL), Johansen and Juselius Cointegration, and dynamic ordinary least square (DOLS). The empirical results found that institutional quality and climate change are cointegrated into economic growth in the long run. Furthermore, average rainfall, instutional quality , and capital stimulate economic growth in Somalia in the long run; whereas the average temperature has a devastating effect on economic growth in the long run. These results are robust for various econometric methods. However, the study proposes implementing policies related to climate adaptability and mitigation strategies, and improving institutional quality such as; law and order, government effectiveness, and bureaucratic quality, as these will confirm sustainable economic growth in the long run.

1. Introduction

The vast empirical studies conducted in the climate change literature assert that climate change is already impacting the economies of both developed and developing nations and will continue to do so for many years to come (Rising *et al* 2022). More specifically, climate change impacts the economic output of the countries in various channels such as through decreasing agriculture sector output, labor productivity, or increasing energy consumption (Huang *et al* 2021). In the case of the output channel, climate change impacts—rising temperature, inconsistent rainfall patterns, dry spells, water scarcity, land degradation, floods, prolonged drought incidents, and higher sea levels - may influence the global agricultural systems one way or the other which in turn hampers food security whether it is related to food availability, food access, food stability, and food consumption (Peng and Berry 2018). Raddatz (2009) found that extreme weather patterns and events have a significant adverse effect on developing economies' GDP, reducing 0.6 percent. Dell *et al* (2009) found similar results using data from 12 countries in North and South America by measuring climate change variables using rising temperatures. Alagidede *et al* (2016) and Abidoye and Odusola (2015) documented that climate change reduces the economic growth of African economies. Moreover, Hsiang (2010) studied the nexus between climate change and economic growth on one hand, and climate change and labor productivity on the other hand. It was observed that climate change affects labor productivity negatively—thus impeding economic growth. Dell *et al* (2012) supported this finding when examining the same nexus. Using global panel data, it was reported that climate change undermines labor

productivity by about 2%–21% (Gosling *et al* 2019). In addition to this, climate change induces an energy usage upsurge, especially rising ambient temperatures during the summer seasons since it boosts demand for cooling. Huang *et al* (2021) predict that china's energy demand will increase by 1.89–1.94 times in 2100 due to climate change—rising temperatures. This will decrease economic growth by 8.19 to 12.05 percent.

Albeit the above studies show the impeding effect of climate change on economic productivity both in developed and developing economies, however, it is important to note here that the severity and the level of the impact vary from one county to another country depending on many factors, such as country's economic level, geographic location, climate change adaptability, foreign direct investment, quality intuitions, and technology access (Adom and Amoani 2021). For income level, the literature asserts that the effect of climate change is more felt in low-level income countries. Tol (2018) discovered that the inhibiting economic effects of rising temperature and rainfall variabilities are very high in developing economies, such as Africa, as a result of poverty. Recently, Baarsch *et al* (2020) indicated that climate change impacts hit very hard on countries located in Western and Eastern regions of Africa which are poorer economically. Interestingly, Dell *et al* (2012) compared the effect of temperature shocks on poor and rich economies; however, they found that temperature shocks undermine economic growth in the case of poor economies, but failed to establish similar findings in rich economies.

Even among developing countries, sub-Saharan African countries are more prone to climate change impacts (Warsame and Sarkodie 2022) due to their over-reliance on the agriculture sector and lack of diversification between economic sectors. It is estimated that 30% of the gross domestic product (GDP) of sub-Saharan Africa and 60% of employment generation are coming from the agriculture sector contribution (Thornton *et al* 2009). Another study estimates that the agricultural sector contributes to 40% of the GDP of East African economies and it provides the livelihood for approximately 80% of the population (Mahoo *et al* 2013). In Somalia, agriculture—with its broad scope—represents 70 percent of the GDP (Ministry of Planning, Investment and Economic Development, 2019). Also, Warsame *et al* (2021) stated that the agriculture sector significantly contributes to the Somali economy by generating 93% of the country's total export earnings.

Besides the horrendous effect of climate change on growth, the other factor that impacts the economic production of the nations is the type of institutions they have. Indeed, institutional quality is an important factor in promoting a country's economic growth. The empirical literature has illustrated several institutional factors that have a crucial role in influencing economic growth, such as rule of law, government effectiveness, and democracy. Olson *et al* (1998) discovered that institutional factors have a significant impact on total factor productivity using panel data and they found that countries with strong institutions have exhibited better productivity. Acemoglu *et al* (2005) argued that institutional quality plays a key role in determining economic growth in the long-term than in the short-term. Lau *et al* (2014) observed that institutional quality has a positive impact on Malaysia's economic growth. Similarly, Nawaz (2015) and Şaşmaz and Sağdiç (2020) discovered a positive correlation between institutions and economic growth. Islam and Shindaini (2022) found a similar result in Bangladesh. Recently, Ashraf (2023), using the ARDL bound test, revealed that political stability plays a key role in enhancing economic growth in Pakistan. In a cross-country study of Belt and Road Initiative countries, Ashraf (2022) assessed the impact of political instability on economic complexity. It was reported that political instability hampers economic complexity in sampled countries.

In the context of Somalia, both climate change and the quality of institutions exert substantial impacts on domestic production. Indeed, it has paramount importance to examine this subject in Somalia since it has been ravaged by recurrent civil wars, political instabilities, corruption, bad governance, and a lack of rule of law. Further, Somalia suffered several instances of climate change consequences. Specifically, climate change incidents—mainly droughts and floods –caused food insecurity, poverty, unemployment, and overall economic loss (Warsame *et al* 2022d). In the case of climate change impact, several studies highlighted the impact of climate change on agriculture production in Somalia (Warsame *et al* 2021, Warsame *et al* 2022b, Warsame *et al* 2022a, Warsame *et al* 2022c) and Africa (Abdi *et al* 2022). According to the authors' best knowledge, there is no prior empirical study on the economic growth-climate change-institutional quality nexus in Somalia; even though, it is known that the country's economic development level is poor and the level of exposure to climatic conditions is extremely high and the institutional quality index is low. However, this study contributes to the literature in several ways. First, it investigates the impact of climate change on economic development in Somalia which is considered one of the most vulnerable countries to climate change in the world. Second, this undertaking incorporates institutional factors to determine the simultaneous effect of climate change and institutional quality on economic growth in Somalia using annual time series data spanning 1985–2017. Thus, understanding the combined effect of the two variables on Somalia's economic growth using an econometric model is crucial for policymakers for designing coherent and effective policies that will help to combat climate change impacts as well as promote quality institutions. However, so far there is no study attempted to examine this issue despite its urgency and importance to the country's economic growth vision. Thus, this study will

Table 1. Variables' descriptions and sources.

Real GDP per capita	EG	Real GDP per capita (Constant 2010).	OIC database
Rainfall	R	Average annual precipitation (mm)	World Bank
Temperature	T	Average annual temperature in (°C)	World Bank
Capital	K	Gross fixed capital formation constant in the US million dollars.	OIC database
Law and order	LO	'This variable contains two elements which are 'law' and 'order'. To assess the (Law) element, the strength and impartiality of the legal system are considered, while the (Order) element is an assessment of popular observance of the law'.	International country guide risk (ICRG)

examine this issue using the ARDL, Johansen and Juselius Cointegration, and DOLS method for the period 1985–2017.

Following this section, section two presents the data and econometric model, section three estimates the model, and discusses the findings. Section four will conclude the study along with policy recommendations.

2. Data and methods

2.1. Data

This undertaking empirically assesses the contribution of institutional quality and climate change to economic growth in Somalia for the period 1985–2017. Somalia has been constantly suffering from climate change consequences during a malfunctioning government period since 1991. There is a dire need to determine the role of climate change and institutional quality in economic growth simultaneously. For this purpose, we extracted data from various sources such as the Organization of Islamic Cooperation, World Bank, and International country guide risk (ICRG). Economic growth is used as a dependent variable, whereas rainfall, temperature, capital formation, and law and order as explanatory variables. We used law and order as a measurement of institutional quality. This variable contains two elements which are 'law' and 'order'. To assess the (Law) element, the strength and impartiality of the legal system are considered, while the (Order) element is an assessment of popular observance of the law. A country is given a high rating of '6' if law and order are in place, but it is given a low rating of '1' if it suffers from a high crime rate, and no law and order is in place. The data sources and measurements are reported in table 1.

2.2. Method

Our model specifications follow the work of Adom and Amoani (2021), Bond *et al* (2010), and Dell *et al* (2012) who linked up the relationship between climate change and economic development. Theoretically, climate changes impact economic growth through two major channels; one is through decreasing the output level, especially the agriculture yields and the other one is through decreasing the country's capital level (machinery and infrastructure) and impacting investment. More specifically, climatic conditions—changes in temperature and rainfall—cause damages to roads, property, and agricultural lands which forces the country to re-invest again and this affects a country's ability to grow. So, for this purpose, we have added temperature, rainfall, and capital accumulation into our model to test this theoretical relationship and see the empirical relationship. On the other hand, we have used the economic theory of Acemoglu *et al* (2005) which examines the relationship between institutional quality and economic growth. The reason being adding institutional variables into the model are to see if there is any difference between when a county has poor intuitional quality and quality institutions in the fight against the climate change impacts. As stated above, climate change impacts a country's capital level, so the level of institutional quality the country has will determine the response to climate change impacts.

We utilized the ARDL bound test to determine the long- and short-run relationship of the interested variables (Pesaran *et al* 2001). This method is preferred over other Cointegration methods for several reasons. First, time-series data often contain trending volatility which violates the assumption of stationary in the same order. The ARDL method is good at estimating the series that are stationary at the level I(0), first order I (1), or the combination of both hence implying that this method does not require pre-testing variables like previous Cointegration methods. Second, the ARDL technique estimates the short- and long-run coefficients simultaneously. Third, running a small sample size is another advantage that is preferred for the ARDL technique.

The linkage of economic growth with independent variables is expressed as follows: $Economic\ growth = f(\text{rainfall} + temperature + capital + \text{law and order})$

Table 2. Descriptive statistics.

	lnRGDPC	lnAR	lnAT	lnK	lnLO
Mean	4.649	3.118	3.304	19.201	1.189
Median	4.523	3.105	3.302	19.186	1.185
Maximum	5.064	3.509	3.334	19.693	1.609
Minimum	4.498	2.795	3.283	18.922	0.693
Std. Dev.	0.211	0.164	0.013	0.197	0.279
Skewness	1.055	0.153	0.399	0.569	0.114
Kurtosis	2.281	2.980	2.796	2.617	1.634
Jarque-Bera	6.624	0.126	0.907	1.926	2.555
Probability	0.036	0.939	0.635	0.381	0.278
Correlation					
lnRGDPC	1				
lnAR	−0.153	1			
lnAT	−0.533	0.243	1		
lnK	0.739	0.034	−0.071	1	
lnLO	0.568	−0.055	−0.416	0.1961	1

The association of economic growth with the explanatory variables—rainfall, temperature, capital, and law and order is transformed into a log-linear model to avoid the issue of heteroskedasticity, and can be expressed as follows:

$$lnEG_t = \beta_0 + \beta_1 lnR_t + +\beta_2 lnT_t + \beta_3 lnK_t + \beta_4 LO_t + +\varepsilon_t \quad (1)$$

$lnEG_t$, lnR_t, lnT_t, lnK_t, and $lnLO_t$ represent the natural logarithm of economic growth, rainfall, temperature, capital, and law and order respectively. ε_t is the disturbance term.

This undertaking aims to assess the long- and short-run relationship of economic growth with rainfall, temperature, capital, and law and order. Following the empirical works of (Fankhauser and Tol 2005; Acevedo *et al* 2020; Magazzino *et al* 2021; and Khurshid *et al* 2022), the ARDL long- and short-run Cointegration equation is expressed as follows:

$$\begin{aligned}\Delta lnEG_t &= +\alpha_0 + \alpha_1 lnEG_{t-1} + \alpha_2 lnR_{t-1} + \alpha_3 lnT_{t-1} \\ &+ \alpha_4 lnK_{t-1} + \alpha_5 lnLO_{t-1} + \sum_{i=0}^{q} \Delta\beta_1 lnEG_{t-k} \\ &+ \sum_{i=0}^{p} \Delta\beta_2 lnR_{t-k} + \sum_{i=0}^{p} \Delta\beta_3 lnT_{t-k} + \sum_{i=0}^{p} \Delta\beta_4 lnK_{t-k} \\ &+ \sum_{i=0}^{p} \Delta\beta_5 lnLO_{t-k} + \varnothing \mathrm{ECT}_{t-1} \end{aligned} \quad (2)$$

Where α_0 is the constant, $\alpha_1 - \alpha_5$ are the long-run coefficient variables, $\beta_1 - \beta_7$ represent the short-run parameters, p shows the optimal lags of the regressors, q stands for the regressand optimal lags, Δ- first difference sign—indicates short-run variables and $\varnothing$ is the coefficient of the error correction term.

Determining the bound test of long-run Cointegration is the first step of the ARDL technique. The null hypothesis is specified as:

H_0: $\alpha_1 = \alpha_2 = \alpha_3 = \alpha_4 = \alpha_5 = 0$ |The null hypothesis (H_0): The series are not cointegrated in the long run.

H_1: $\alpha_1 \neq \alpha_2 \neq \alpha_3 \neq \alpha_4 \neq \alpha_5 \neq 0$|The alternative hypothesis (H_a): The series are cointegrated in the long run.

To discard the null hypothesis, the Wald F-statistics should be above the upper bound critical values.

3. Empirical analysis and discussion

3.1. Descriptive statistics

Summary statistics of the sampled variables are presented in table 2. It is observed mean values of economic growth (4.6), average rainfall (3.1), temperature (3.3), capital (19.1), and law and order (1.1). Capital and economic growth have the highest maximum values of 19 and 5, respectively. Law and order are recorded to have the highest standard deviation value of 0.27 which means its values are scattered compared to other variables. All the sampled indicators are positively skewed, and they are independently and identically distributed except economic growth which is statistically significant. Besides, the correlation of the sampled variables is also reported in table 2. It was established that average rainfall and temperature are negatively

Table 3. Variance inflation factors.

Variable	Coefficient variance	Uncentered VIF	Centered VIF
lnAR	0.0098	397.776	1.0676
lnAT	2.0549	92640.67	1.2839
lnK	0.0066	10139.90	1.0421
lnLO	0.0040	24.7392	1.2532
Constant	24.4624	101046.1	NA

Table 4. Unit root tests.

Variable	ADF	PP
lnEG	−3.1825	−1.1392
ΔlnEG	−2.7325	−5.9296***
lnR	−5.6048***	−5.9479***
ΔlnR	−5.9099***	−28.2423***
lnT	−5.1667***	−5.1635***
ΔlnT	−8.5479***	−22.531***
lnK	−9.2775***	−1.0519
ΔlnK	−4.1197**	−8.6822***
lnLO	−2.1049	−2.1049
ΔlnLO	−4.2597**	−4.2155**

Δ represents first difference variables.
*, **, and *** exhibit the significance level of 10%, 5%, and 1% respectively. We reported the t-statistics of the trend and intercept only.

associated with economic growth, whereas capital and law and order are positively related to economic growth. The correlation result also displays there is no multicollinearity between the independent variables since there is no coefficient that is greater than 0.9. A correlation of 0.9 signifies a perfect correlation which is undesirable. Moreover, the results of multicollinearity using the correlation are verified by the results of the variance inflation factor (VIF), presented in table 3, which confirms that the explanatory variables are not perfectly correlated.

3.2. Unit root test

Testing the integration order of time series data is compulsory. Hence, the unit root test is presented in table 4. It revealed that the sampled series are integrated in a mixed order of integration. For example rainfall, temperature, and capital are stationary both at a level I (0) and the first difference I (1). On the other hand, law and order, and economic growth are stationary at the first difference I (1) only. Thus, the ARDL bound test is appropriate for the characteristics of our data.

3.3. The bound test results

Determining the long-run Cointegration between the regressand and regressors is compulsory before estimating the long and short-run coefficients of the parameters. The bound test result is reported in table 5. It shows that the F-statistics (13.14) is above the upper bound critical value (6.56) at a 1% significance level. This implies that the independent parameters—rainfall, temperature, law and order, and capital—are cointegrated into economic growth in the long run. Since our sample size is less than 80 observations, we employed the Narayan critical values which are robust for the small sample size.

The long-run coefficient results of the independent variables, presented in table 6, revealed that all the independent variables are significant at different significance levels. Average rainfall, law and order, and capital stimulate economic growth in Somalia in the long run; whereas the average temperature has a devastating effect on economic growth in the long run. Interpretively, a 1% increase in rainfall, law and order, and capital lead the economic growth to increase by about 0.12%, 0.033%, and 0.15% respectively in the long run. On the contrary, a 1% increase in temperature results in economic growth decreasing by about 2.87% in the long run in Somalia. Notably, the temperature rise has the highest effect on economic growth since it is elastic and has the largest coefficient elasticity compared to other regressors.

Climate change undermines the economic growth in Somalia. The agriculture sector contributes the largest portion of the gross domestic product in Somalia, while agriculture is the most susceptible sector to climate

Table 5. F-Bounds cointegration tests.

Model	F-statistic	Significance	Bounds test critical values	
LnEG = *f*(lnR, lnT, lnLO, lnK)			D (4)	
			I (0)	I (1)
	13.1476	1%	4.824	6.56
		5%	3.326	4.73
		10%	2.752	3.922

D = number of independent parameters.

Table 6. Long-Run coefficients.

Variable	Coefficient
Constant	7.2954***
	(3.9254)
lnAR	0.1206***
	(3.3038)
lnAT	−2.8767***
	(−4.8010)
lnLO	0.0331*
	(1.8915)
lnK	0.1503***
	(5.1555)

Note that *** and ** refer to significance at 1% and 5% levels, respectively. Values in parenthesis are the t-statistics.

change—temperature and rainfall. Despite Somalia having two rivers, a substantial percentage of the agricultural production is rain-fed. Several empirical studies conducted in Somalia had shown that rainfall stimulates food crop production (Warsame *et al* 2021, Warsame *et al* 2022a). Warsame *et al* (2022b) documented that an increase in rainfall stimulates livestock production in Somalia. A similar result was observed by Fankhauser and Tol (2005) that reported an increase in rainfall enhances economic growth. Some others underscored that temperature has a devastating effect on agriculture production (Warsame *et al* 2022c).

Further, an increase in temperature level results in rain failures, drier conditions, and evapotranspiration which could impact economic productivity. Agriculture is considered the most susceptible sector to climate change regardless of the development level of countries, it was observed that a rising level of temperature undermines agriculture, forestry, and fishing in the United States of America where the agriculture sector represents 1 percent of the gross domestic product (GDP) (Colacito *et al* 2018). Somalia is susceptible to climate change because of the high dependence on agriculture and weak adaptation capacity of the country. It is predicted that the temperature in Somalia will increase by about 1.4–1.−9 °C by 2030 compared to pre-industrial levels. The very heat days with a maximum temperature of 35 °C are also set to increase in the country specifically in South and central Somalia. Consequently, water availability will decrease by half in 20280 hence underscoring the severe effects of rising temperatures in Somalia (Reliefweb 2022). Our empirical result highlighted that a temperature rise substantially impedes economic productivity in the country. This result corroborates the findings of Acevedo *et al* (2020) who found that a temperature rise impedes economic growth in Panel countries, but the impact is more pronounced in hot low-income countries. Using panel data, Dell *et al* (2009) concluded that a 1% increase in temperature impedes economic growth by about 1.3% in poor countries.

Mounting empirical research evidence has shown that institutional quality is a greasing wheel of growth. For instance, Christoforidis *et al* (2021) concluded that institutional quality enhances growth in 18-panel countries. Similarly, Nedić *et al* (2020) revealed that institutional quality components tend to rise the growth in Western Balkan countries. More specifically, the effectiveness of government and regulatory quality has a strong effect on growth, whereas rule of law and corruption control effects on growth are weak but very imperative. Similar findings were discovered by Ahmed *et al* (2021) in South Asian countries, Ashraf *et al* (2022) in Belt and Road Initiative countries, and Salman *et al* (2019) in Thailand, South Korea, and Indonesia. Boateng *et al* (2021)

Table 7. Short-run dynamic effect.

Variable	Coefficient	t-Statistic
Constant	0.3352**	(2.1558)
ECT (−1)	−0.1022**	(−2.3144)
Δ (lnRGDPC (−1))	−0.2077	(−1.6024)
Δ (lnAR)	−0.0136	(−0.8004)
Δ (lnAR(−2))	0.02719	(1.4145)
Δ (lnAR(−3))	0.0333*	(1.7567)
Δ (lnAT)	(0.0938)	(0.2617)
Δ (lnK)	0.4491***	(5.7920)
Δ (lnK(−1))	0.1027	(1.2011)
Δ (lnK(−2))	0.0218	(0.4729)
Δ (lnLO)	−0.0937**	(−2.4496)
Diagnostic Tests		
Serial correlation	0.134143	[0.6937]
Heteroskedasticity Test	0.7129	[0.5873]
Normality Test	0.5851	[0.7464]
Reset Test	2.1951	[0.1665]
Adjusted R^2	0.9260	

T-statistics and P-values are in parenthesis and brackets respectively. Δ Is first difference variable.

uncovered that institutional quality improves economic growth in Sub-Saharan African countries but failed to establish the mediating effect of institutional quality on the foreign aid volatility-growth nexus. Strong institutions imply strong economic growth. Good institutions design and implement rules and regulations in public by applying contextual controls. On the other extreme, weak institutions lead to corruption, an ineffective bureaucratic system, the absence of rule of law, and weak environmental regulations. Somalia has endured political instability in the last three decades; even sometimes there were no government institutions. Consequently, this has undermined the infrastructure, economic growth, and livelihoods of the population. However, improving institutional quality by restoring rule of law contributes to economic growth positively as our result shed the light on.

The short-run dynamic effect and ECT are reported in table 7. Its results indicated that both average rainfall and temperature are statistically insignificant. Hence, they do not have any meaningful effects on growth in the short run. Capital tends to raise economic growth in the short run. A 1% increase in capital leads economic growth to increase by 0.449% in the short run. On the contrary, law and order tend to decrease economic growth in the short run. A 1% increase in law and order reduces economic growth by about 0.0937%. More importantly, the ECT is statistically significant and has a negative coefficient - which indicates the speed of adjustment that the variables converge. Any shock disequilibrium that occurs in economic growth in the short run will be adjusted by about 10% by the interested independent variables annually in the long run.

Furthermore, the diagnostic tests and model stability are also reported in table 7 and figure 1, respectively. Model diagnostic tests such as heteroskedasticity, model misspecification, serial correlation, and normality tests were performed. We found that the model is free from heteroskedasticity, serial correlation, and the model specification is correctly specified. Moreover, the data is normally and identically distributed as revealed by the normality test. The goodness fit of the model is good because the adjusted R-squared is 0.92. It is interpreted as 92% of the variations that occur in economic growth are responsible for the scrutinized explanatory variables—average temperature, rainfall, law and order, and capital. The model is also stable as shown in figures 1 and 2 of the Cusum and Cusum square tests respectively.

3.4. Robust analysis

To find out effective results which are key for policy implications, we perform a robust analysis of the ARDL bound test. We utilize Johansen and Juselius Cointegration, and DOLS reported in tables 8 and 9 respectively. The empirical result of the multivariate Cointegration revealed the existence of long-run Cointegration of the sampled variables. There is at least one cointegrating vector between the interested variables. Moreover, the DOLS indicated rainfall, capital, and law and order stimulate economic growth, whereas the temperature significantly hampers it in the long run in Somalia. A 1% increase in rainfall, capital, and law and order lead the economic growth to increase by about 0.39%, 0.65%, and 0.14% respectively in the long run. Average temperature reduces economic growth by about 10.4% in the long run for a 1% increase in average temperature. However, both the Johansen Cointegration and DOLS have verified the long-run results of the ARDL bound test.

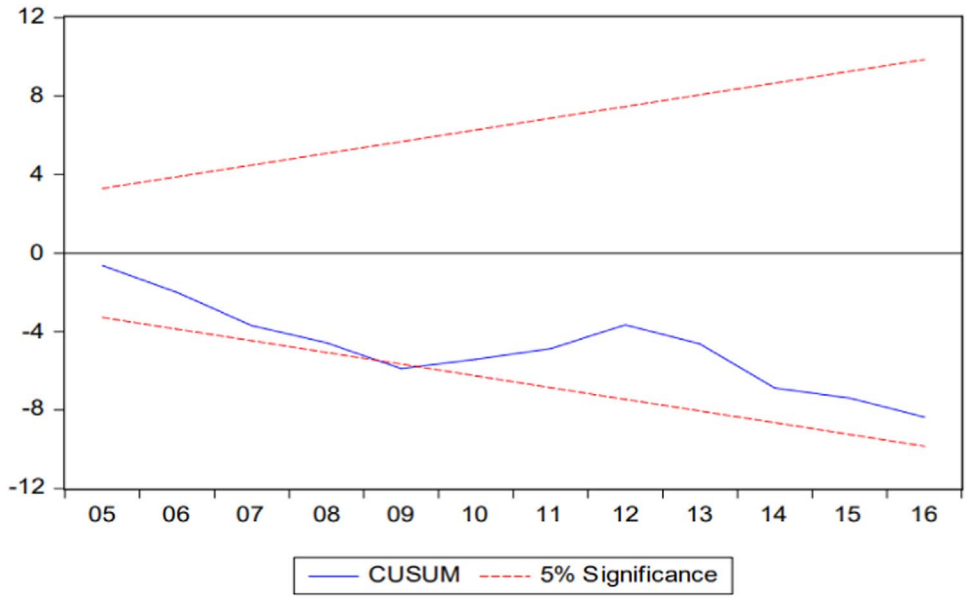

Figure 1. CUSUM test.

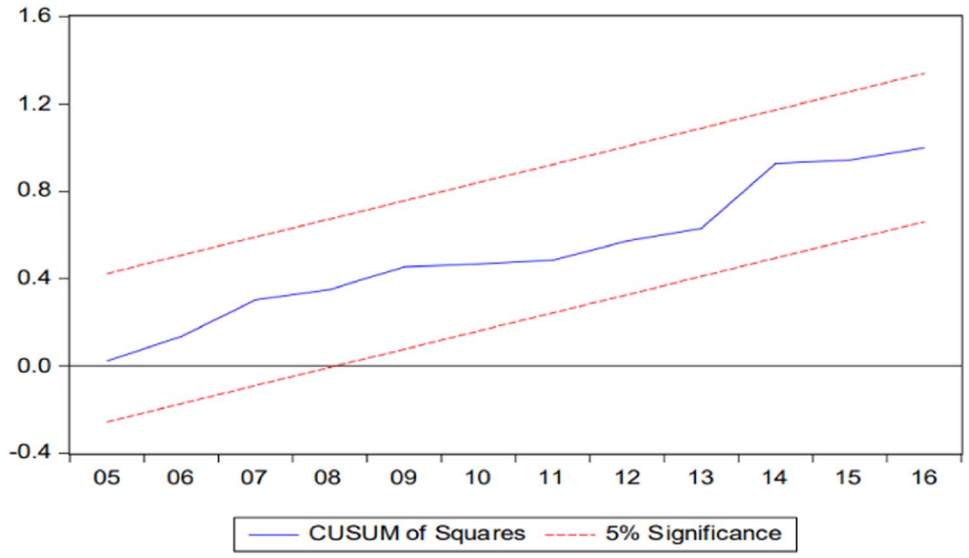

Figure 2. CUSUM square test.

4. Conclusion and policy implications

Global warming, rising temperature, and rainfall variability adversely affect sustainable economic growth—thus undermining the standard of living and livelihoods of the Somali population. Indeed, no empirical study has examined this line of research. In this regard, this undertaking empirically assessed the role of climate change—temperature and rainfall –, and institutional quality in economic growth in Somalia. To avoid model misspecification and biased results, we incorporate gross capital formation as a control variable in the model. A long-run Cointegration between economic growth and the interested independent variables is detected. Furthermore, average rainfall, law and order, and capital stimulate economic growth in Somalia in the long run; whereas the average temperature has a devastating effect on economic growth in the long run. Notably, law and order hamper economic growth in the short run while capital enhances economic growth in the short run. Temperature rise has the highest effect on economic growth since it is elastic and has the largest coefficient elasticity compared to other regressors. Based on the empirical findings, the study proposes several policy recommendations. First, implementing policies related to climate adaptability and mitigation strategies should be the main priority of the policymakers. This will reduce the economic growth vulnerability to climate change

Table 8. Result of Johansen cointegration.

Hypothesized	T-Statistic	Critical	Value	Probability
Trace test				
	r ⩽ 0 [a]	87.67968	69.81889	0.0010
	r ⩽ 1 [a]	51.16116	47.85613	0.0237
	r ⩽ 2	25.99959	29.79707	0.1287
	r ⩽ 3	7.130833	15.49471	0.5625
	r ⩽ 4	0.003894	3.841466	0.9490
Maximum Eigenvalue				
	r ⩽ 0 [a]	36.51853	33.87687	0.0236
	r ⩽ 1	25.16157	27.58434	0.0990
	r ⩽ 2	18.86876	21.13162	0.1007
	r ⩽ 3	7.126939	14.26460	0.4743
	r ⩽ 4	0.003894	3.841466	0.9490

[a] Indicates the rejection of the null hypothesis at the 5% level.

Table 9. Dynamic least squares (DOLS).

Variable	Coefficient	Std. Error	T-Statistic	Prob.
lnK	0.6563	0.0483	13.5868	0.0000
lnAT	−10.4368	1.8732	−5.5717	0.0001
lnAR	0.39447	0.1213	3.2527	0.0069
lnLO	0.14937	0.0423	3.5355	0.0041
Constant	25.1015	6.0683	4.1365	0.0014
R-squared	0.988564			
Adjusted R-squared	0.973316			

shocks. Second, improving institutional quality such as; law and order, government effectiveness, and bureaucratic quality, will confirm sustainable economic growth in the long run.

This study is only limited to analyzing the impact of climate change—measuring temperature and rainfall—and institutional quality on economic growth. The availability of climate change data such as wind speed and humidity is restricted in Somalia. However, future studies should examine the impact of other meteorological factors such as wind speed and humidity on economic growth.

Data availability statement

The data that support the findings of this study are available upon reasonable request from the authors.

Declaration

Compliance with ethical standards.

Ethical approval

Not applicable.

Competing interests

The authors declare that they have no conflicts of interest.

Consent to participate

Not applicable.

Consent to publish

Not applicable.

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Credit author statement

Abdimalik Ali Warsame: Conceptualization, data collection, writing the original draft. Ibrahim Abdukadir: Writing the introduction and literature. Hassan Abdikadir: Writing methodology Galad Mohamed: Reviewing and Editing.

ORCID iDs

Abdimalik Ali Warsame https://orcid.org/0000-0001-6130-5607

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