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Examining the confluence of climate change and conflicts on agricultural and livestock exports in Somalia

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Abstract

Climate-induced extreme weather events and conflicts are jointly contributing to disruptions in agricultural supply chains and destabilizing global food trade. Since the literature has identified that variations in climatic conditions hamper farming and animal raising, it is necessary to explore the consequences of climate change on crop and livestock exports in order to implement policies that mitigate the exposure and enhance exports. In this context, this study aims to examine the confluence of climate change and conflicts—internal and external—on agricultural and livestock exports in Somalia during 1985–2017. The evidence from the cointegration analysis verified the presence of a consistent long-run cointegration between the variables. The empirical results of the ARDL approach indicate that average rainfall enhances agricultural and livestock exports in Somalia in the short-run and long-run, while mean temperature particularly hampers agricultural exports in the long-run. Despite livestock production was found to be statistically insignificant, crop production positively contributes to agricultural exports. In addition, increases in rural population enhance both export categories in the short-run and long-run. A striking finding from the study indicates that internal and external conflicts decrease crop and animal exports in the long-run, although the coefficients of external conflicts were statistically insignificant. The long-run findings were validated using the FMOLS cointegration approach. Moreover, the causality findings demonstrate a unidirectional causality from agricultural exports to precipitation, temperature fluctuations, and internal conflicts. Furthermore, the study shows that agricultural labor Granger causes farm and livestock exports. To this end, this study recommends policymakers promote product diversification, foster sustainable land management practices, facilitate market access, and invest in resilient farming systems.

1. Introduction

The sustainability and competitiveness of agricultural exports became a matter of international significance as the world grapples with the challenges of a changing climate and geopolitical instabilities. Over the past decade, the surface temperature has increased by 1.1 °C above the 19th century due to anthropogenic activities, mainly those resulting from greenhouse gas emissions (IPCC 2022, Warsame *et al* 2023). Population growth, urbanization, deforestation, expanding industrialization, and conflicts are considered the main factors exacerbating environmental degradation (Chandio *et al* 2022, Satari Yuzbashkandi and Khalilian, 2020, Usman *et al* 2021, Abdi *et al* 2023a). Climatic variability is associated with unpredictable rainfall patterns, heat waves, sea-level rise, desertification, and glacier retreat, resulting in increased natural disasters and decreased soil moisture (Chandio *et al* 2021). In regions highly reliant on climate-sensitive livelihoods, climate hazards are projected to worsen water availability and food insecurity (Duc *et al* 2019, IPCC, 2022). In addition, Calzadilla *et al* (2014) indicated that global climate change is predicted to alter agricultural productivity worldwide, resulting in lower food output and higher food costs. Accordingly, developing nations experience larger reductions in agricultural exports due to temperature increases (Machovina and Feeley, 2013, Barua, 2018, Tanure *et al* 2020). Most African countries are predicted to suffer the greatest losses from yield shocks, resulting in GDP declines (Dellink *et al* 2017, Abdi *et al* 2023b). Since the poorest rural populations are the most vulnerable to the effects of climate change, Abdi *et al* (2023a) suggested that it exacerbates social unrest in already conflict-prone economies.

Climate change poses a significant threat to agricultural growth in developing economies due to their substantial dependence (Ekpenyong and Ogbuagu, 2015, Busari and Kehinde, 2018). Since extreme temperatures indirectly cause greater water stress and soil moisture reduction, it leads to failed crop harvests and a shift in the growing season duration (Zhao *et al* 2017, Pickson *et al* 2020, Ngoma *et al* 2021). Due to variations in the geographical and seasonal distribution of precipitation, the supply and demand of agricultural water resources became more unstable (Luo *et al* 2015, Dubey and Sharma, 2018). In addition, the rising frequency of extreme climatological occurrences affects the hydrological cycle and, ultimately, irrigated crop production (Knox *et al* 2012, Adhikari *et al* 2015). Considering that most crops depend solely on their respective regions' weather, climate change is an important element that determines agricultural production and the cropping pattern (Ahsan *et al* 2020, Kumar *et al* 2021). As a result of the deteriorating environmental conditions, farmland productivity diminishes, which alters global agricultural trade patterns. Due to supply shortfalls, Chandio *et al* (2022) point out that the production of dairy products, agricultural trade, and the price of food grains may all be adversely affected by climate change. Accordingly, the volatility of agricultural production can be transmitted to the competitiveness of agricultural products in rival countries, which would affect the country's economic growth. Jones and Olken (2010) underlined that increased temperatures had significant negative effects on the export growth of poor nations but had little influence on that of advanced nations. Therefore, climate-related disruptions in regions vital for agricultural exports highlight the urgency of diversifying supply chains and adopting climate-resilient farming practices (Abdi *et al* 2023c).

Because of indicators including population growth, increased incomes, and dietary changes, the worldwide demand for livestock and associated products expanded dramatically (Nardone *et al* 2010). Extreme weather events are posing a worldwide danger to the livestock industry by increasing animal mortality, acute morbidity, and the prevalence of common illnesses, which has a detrimental effect on the means of subsistence and food security of pastoralists and agro-pastoralists (Warsame *et al* 2022). This disruption is due to the vulnerability of rainfed agricultural and livestock herding systems to climate change and variability, which makes it more difficult for the livestock sector to meet the growing demand for its products. Moreover, the supply of livestock exports declines since reduced animals' access to water and forage lowers productivity (Majid 2010, Mihiretu *et al* 2019). However, because the livestock sector is vulnerable to climatic shocks, rural populations are particularly facing its adverse repercussions (Ngoma *et al* 2021). Poor productivity and high production costs lead to reduced farmers' incomes in developing countries (Kumar *et al* 2021). This increases export prices among leading producers while raising concerns for nations heavily reliant on imports (Iizumi and Ramankutty 2016). Therefore, climatic disasters may necessitate technological changes, raise trade prices, and insurance rates (Oh and Reuveny 2010). Besides, Abdi *et al* (2023a) highlight that rural income losses might cause societal problems, including land desertion and unrest, when the capacity for governance is low. Rising temperatures and water scarcity due to climate change, exacerbated by conflict, pose significant challenges to the sustainability and competitiveness of livestock exports.

1.1. Climate patterns and export trends in Somalia

Since pasture growing in SSA depends mostly on rainfall, these nations are more vulnerable to weather abnormalities (Abdi *et al* 2023b, Warsame *et al* 2022). The poorest rural populations in SSA are particularly vulnerable to the consequences of climate change since agricultural and livestock production is crucial for livelihood, employment, export revenue, and economic progress (Attiaoui and Boufateh 2019). Global warming is expected to increase temperature variability in East Africa by 2 °C to 4 °C by the end of the 21st century (Adhikari *et al* 2015). Moreover, the average annual rainfall in the region is higher in the highlands, from 800 to 1200 mm, while it is lower in northeastern Kenya and Somalia (Nicholson 2017). By means of export earnings, the agriculture and livestock industries contribute significantly to the socioeconomic status of the Somali economy (Mtimet *et al* 2021). At their peak of 533 million USD in 2015, agricultural and livestock exports exceeded their level in the late 1980s by over ten times (World Bank & FAO, 2018). In 2018, the top five exports from Somalia accounted for nearly 83% of total product exports; 82% were sold to only five countries (World Bank, 2021). These are mostly raw, unprocessed commodities susceptible to shocks and extreme weather conditions. Additionally, Somalia's reliance on the export of these goods has made trade swings more pronounced as a result of political unrest and violence (World Bank, 2021). This leads to limited direct market access for farmers, often resulting in uncompetitive market prices for their products (Rehman *et al* 2022).

Over half of Somalia's population resides in rural areas, relying on pastoralism and agro-pastoralism for employment and subsistence (World Bank & FAO, 2018, Majid, 2010). Because of insufficient rainfall, there are

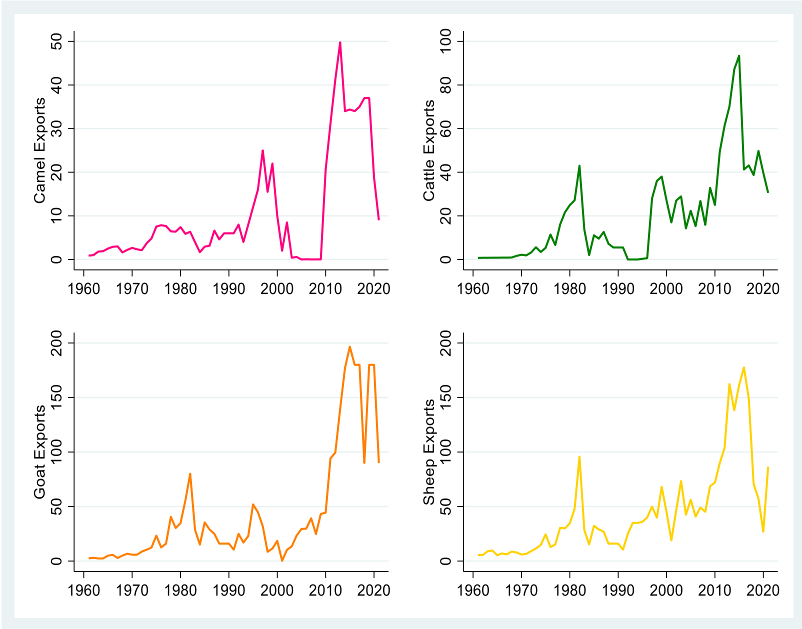

Figure 1. Livestock exports of Somalia from 1960 to 2021. Source: Data compiled from FAO (2023).

disputes over water in central and northern rangelands, which trigger conflicts between agro-pastoralists and nomadic pastoralists (World Bank & FAO, 2018). The livestock value chain in Somalia is mostly supplied by smallholder farmers, whose livelihoods are intimately related to the trade and raising of animals (Mtimet *et al* 2021). According to Mugunieri *et al* (2015), there are two value chains for Somalia's livestock exports: sacrificial exports during the Hajj season, mainly to Saudi Arabia, and commercial livestock exports outside of festival seasons. Between Ramadan and Dhul-Hijja, a significant market for livestock producers and dealers, there is a greater foreign demand for the country's livestock (Mugunieri *et al* 2015, World Bank, 2021). The Hajj season, when prices are especially enormous, accounts for over 70% of the yearly exports of sheep and goats (Majid 2010). In 2020, the COVID-19 pandemic had a major effect on exports during the busiest part of Ramadan (Mtimet *et al* 2021). Following the collapse of the Somali Republic and the breakout of the civil war, livestock exports faced bans by importing countries across the Golf region in 2000–2009 as well as a partial ban in 2016 (Mtimet *et al* 2021). In addition, drought conditions affect the supply of animals suitable for export, and long-distance animal transportation becomes difficult (Majid 2010).

Weather variations, import restrictions, the recent COVID-19 pandemic, and conflicts have significantly negatively impacted livestock exports and productivity, forcing people out of rural areas and causing animal dealers to lose income and export revenues (Majid 2010, World Bank, 2021). Since a large portion of the economy of Somalia and government revenues rely on livestock exports, this leads to economic unpredictability. The export values of camel, cattle, sheep, and goats from Somalia displayed an erratic pattern from 1960 to 2021, as illustrated in figure 1. During the first two decades, cattle, goats, and sheep exports exhibited gradual growth, while camel exports remained lower. After 1980, all these animal exports experienced a decline, attributed to failed rainy seasons, droughts, and civil conflicts that erupted in 1991. Since 2000, livestock exports have been consistently expanded, except for a decline in 2010 due to droughts and the 2011 famine. Despite years of drought and civil unrest, livestock exports in Somalia peaked in 2015 and 2016 due to increased precipitation. However, this increase was temporary, with the value and quantity of agricultural exports facing a decline from 2017 to 2022 due to recurrent droughts and partial import bans by destination countries. In 2021, the leading export destinations for goat and sheep were Oman ($151 million), Saudi Arabia ($33 million), the UAE ($16 million), Qatar ($6.5 million), and Bahrain ($4.7 million). Cattle found top export partners in Oman ($32.8 million), the UAE ($1.4 million), and Bahrain ($1 million), while camel exports were primarily destined for Saudi Arabia ($9.5 million) and Bahrain ($0.05 million).

1.2. Climate change impacts on agriculture and livestock production

In numerous developing nations, environmental shifts lead to reduced crop yields, impacting food security, livelihoods, export earnings, and economic stability. Chen *et al* (2017) examined the effects of climate change on maize yields in China's Hebei Province and discovered sizable hectare-level losses. For every 1 °C rise in temperature or 1mm decrease in precipitation, there is a loss of 150 kg per hectare. In Southeast Asia, Tan Yen *et al* (2019) demonstrated that the increasing variability in local climate and the ENSO phenomenon threaten rice production, affecting local and global food security. Comparably, the evidence suggests that temperature variability has a greater adverse influence on banana output in the Philippines than rainfall does (Salvacion 2020), as well as Malaysian palm oil growth due to dry soil and water stress (Abubakar *et al* 2021). Moreover, Huang (2022) demonstrated that higher temperatures shorten the growing season and reduce crop yields, leading to a decline in output and potentially increasing food crises. Hence, increased irrigation may be necessary since temperature rises might reduce yields for main crops by up to 12.2% every 1 °C (Berardy and Chester 2017). As a result, the empirical studies contended that climate change significantly impacts the food supply, slowing growth rates and increasing instability in grain production.

Global agricultural production is impacted by climate change, with the severity of the effects differing throughout nations according to adaptation, mitigation, and climatic variability (Warsame *et al* 2022). Since industrial nations are less vulnerable to climate-related issues because of their adaptive capacity, the majority of losses occur in lower-income nations (Ali *et al* 2017). By utilizing the Ricardian method, Huong *et al* (2019) examined the influence of climate change on agriculture in Vietnam. The study noted a nonlinear linkage between family income and climatic variables, with net income declining as temperature and rainfall rise. Besides, Bilen *et al* (2022) discovered that extreme weather brings about decreased income, higher costs, and less coffee production across America, Africa, and Asia. Moreover, Jannat *et al* (2022) examined the effects of temperature and precipitation on rapeseed output, consumption patterns, and pricing in developing nations. They found that temperature variations have the greatest influence on rapeseed production and are favorably correlated with the growing seasons while negatively correlated with rapeseed maturity stages.

One of the biggest risks to pastoral livestock keepers is the possibility of substantial livestock losses brought on by repeated severe droughts linked to climate change and variability (Megersa *et al* 2014). According to Henry *et al* (2018), climate change has an indirect impact on livestock systems through changes in feed availability, composition, and quality. It also has a direct impact on animal physiology, behavior, productivity, and well-being. Gashaw *et al* (2014) noted that climate change poses a significant threat to Ethiopia's agriculture, affecting its economy and livestock output. Climate change, livestock illnesses, heat stress, and biodiversity loss are some of the elements that have a detrimental influence on livestock production (Bogale and Erena 2022). Additionally, Warsame *et al* (2022) investigated the short- and long-run effects of climate change on livestock production in Somalia. The empirical results of the ARDL reveal that rainfall and temperature patterns were found to have a significant positive and negative impact on livestock production both in the long run and short run, respectively. By the same token, Nardone *et al* (2010) predict that a global increase in drought will have an impact on crop and fodder output. They contend that a hot environment has a deleterious effect on immunological response, metabolic and health conditions, reproduction, and productivity. In the Guinea Savannah Ecological Zone of Nigeria, Ayanlade and Ojebisi (2019) assessed cattle herders' adaptations to climate change and found that drought is a key climate event that poses a serious danger to livestock productivity.

1.3. Climate change, conflicts, and agricultural value chain

For ages, exporting agricultural products and livestock has been one of the main engines of economic growth in developing nations. However, environmental indicators such as precipitation, temperature, and droughts have significantly impacted their export volumes (Abdi *et al* 2023). To comprehend the potential repercussions and implications for international trade, several studies have concentrated on the connection between climate change and agricultural exports. Muoki *et al* (2020) demonstrated that human activity and rising temperatures lead to unsteady trends in the production and exports of tea, upsetting the cycles of growth and harvest in Kenya. Moreover, the unpredictability of agricultural output reduces domestic supply, leading to a corresponding decrease in the exportation of most crop goods. The evidence from some sub-Saharan African economies indicates that climate change negatively impacts the production of some of their export commodities (Abdi *et al* 2023b). As a result of adverse environmental conditions, the agricultural export supply of Nigeria declined, resulting in a loss of revenue from commodity exports (Ekpenyong and Ogbuagu 2015). Environmental pollution and extreme weather events significantly affect the production and export of essential crops, thereby increasing the volatility of the commodities market (Iizumi and Ramankutty 2016, Abbas 2022, Rehman *et al* 2022, Abdi 2023).

Notably, climatic variations have plenty of consequences for trade, not all of which are easily measured. Khan *et al* (2019) studied the impact of environmental degradation on Pakistan's agricultural exports from 1975 to 2017. The authors found significant impacts on crop production, including wheat, cotton, rice, maize, and tobacco, suggesting that climate change may be the primary cause of the decline in agricultural exports. In addition, Jones and Olken (2010) explored the effects of climate change on disaggregated industries. They discovered that temperature has significant detrimental effects on exports of agricultural products and basic manufacturing but no discernible influence on the output of heavy industries or raw materials. Dallmann (2019) examined the impact of weather fluctuations in the exporter and importer nations on bilateral trade flows from 1992 to 2014. The analysis indicates that temperature fluctuations in the exporting nation and temperature differentials between the exporting and importing nations have a detrimental effect on bilateral trade.

On the other hand, the literature demonstrated that climate variations, along with political instability, diminish trade. For instance, Oh and Reuveny (2010) studied the effect of political risk and climate-related natural catastrophes on bilateral trade and found that both have a detrimental effect on trade. Moreover, Lê (2022) reveals that Vietnam's export growth is hindered by persistent logistics and institutional barriers, while similar economic and institutional quality between trade partners positively impacts agricultural exports. By analyzing trade relationships between SSA nations and the EU-28 for agri-food exports, Engemann *et al* (2023) suggested that strengthening a nation's institutional capacity could increase the stability of its trade relations. Similarly, Fert and Fogarasi (2012) found that improved institutional quality enhances the exports of Central European countries. Based on a gravity model for 2000–2018, Oshota and Wahab (2022) examined the degree to which national institutional quality affects bilateral trade flows in ECOWAS. They found that the ECOWAS trade flows are significantly and favorably impacted by the quality of institutions. In addition, Álvarez *et al* (2018) support the idea that trading with countries with better institutions enhances agricultural and raw material exports. Moreover, Faruq (2011) presented evidence highlighting the association between greater export quality and a better institutional environment.

A plethora of research has been done on how climate change affects agricultural productivity in developing nations (Chen *et al* 2017, Duc *et al* 2019, Ahsan *et al* 2020, Chandio *et al* 2022, Abdi *et al* 2023), but empirical studies evaluating the confluence of climatic variations and conflicts on agricultural and livestock exports are scarce. The few studies on the subject not only omit the case of Somalia, which heavily relies on agricultural and livestock exports but also failed to consider the role of conflicts in conflict-affected countries. Despite the effects of climatic variability on agricultural and livestock exports got less attention in the existing literature, recent empirical studies have used a variety of techniques to explore the linkage between climate change and agricultural output in developing nations (Nardone *et al* 2010, Iizumi and Ramankutty 2016, Attiaoui and Boufateh 2019, Rehman *et al* 2022). Against this background, this research offers fresh viewpoints on the confluence of climate change and conflicts–internal and external–on agricultural and livestock exports in Somalia using yearly data from 1985–2017. This study differs from the previous studies in the following ways. To the best of our knowledge, this study provides the first empirical evidence of the effects of climate change on agricultural and livestock exports in Somalia. Moreover, the preceding studies that considered the linkage did not take into account the role of conflicts in exports in conflict-affected countries, including Somalia. It is noteworthy that the study applies reliable econometric approaches, such as the autoregressive distributed lag (ARDL) bounds testing technique, fully modified ordinary least squares (FMOLS), and Granger causality test, to attain robust findings for policymaking purposes. Moreover, the study's findings seek to inform policymakers on how to improve the efficiency of agricultural supply chains and enhance the resilience of the export sector to both climatic and conflict-related disruptions.

The rest of the undertaking is organized as follows: the second portion presents the methodologies and data sources. The third section exhibits the empirical findings and analysis. The fourth section concludes and suggests relevant policy insights.

2. Econometric methodology

2.1. Data and variables

This study seeks to investigate the effects of climate change and conflicts on agricultural as well as livestock exports in Somalia using time series data from 1985 to 2017. The dependent variable of Model I is agricultural exports, whereas the dependent variable of Model II is livestock exports, which are measured as export values in millions of USD. The regressors include climatic factors such as precipitation, measured average annual rainfall (mm), and temperature, estimated in mean annual temperature (°C). In addition, we consider that agricultural and livestock exports depend on crop production and livestock production, measured as production indices. Since it is widely acknowledged that rural populations in Somalia work in the production of crops and livestock herding, we included rural populations as people living in rural areas in the millions.

Moreover, internal and external conflicts are other explanatory variables that affect agricultural and livestock exports. Both variables take a maximum value of '4' and a minimum value of '0'. A number of '0' denotes a very high threat, whereas a value of '4' denotes an extremely low risk. The risks of civil unrest, political violence, and terrorism represent internal conflicts, while armed conflicts, cross-border disorder, and foreign pressures represent external conflicts. The study utilizes data from various sources, such as the Food and Agriculture Organization (FAO), the Climate Change Knowledge Portal (CCKP), the World Development Indicators, and the International Country Risk Guide (ICRG) database. The choice of this time frame is based on

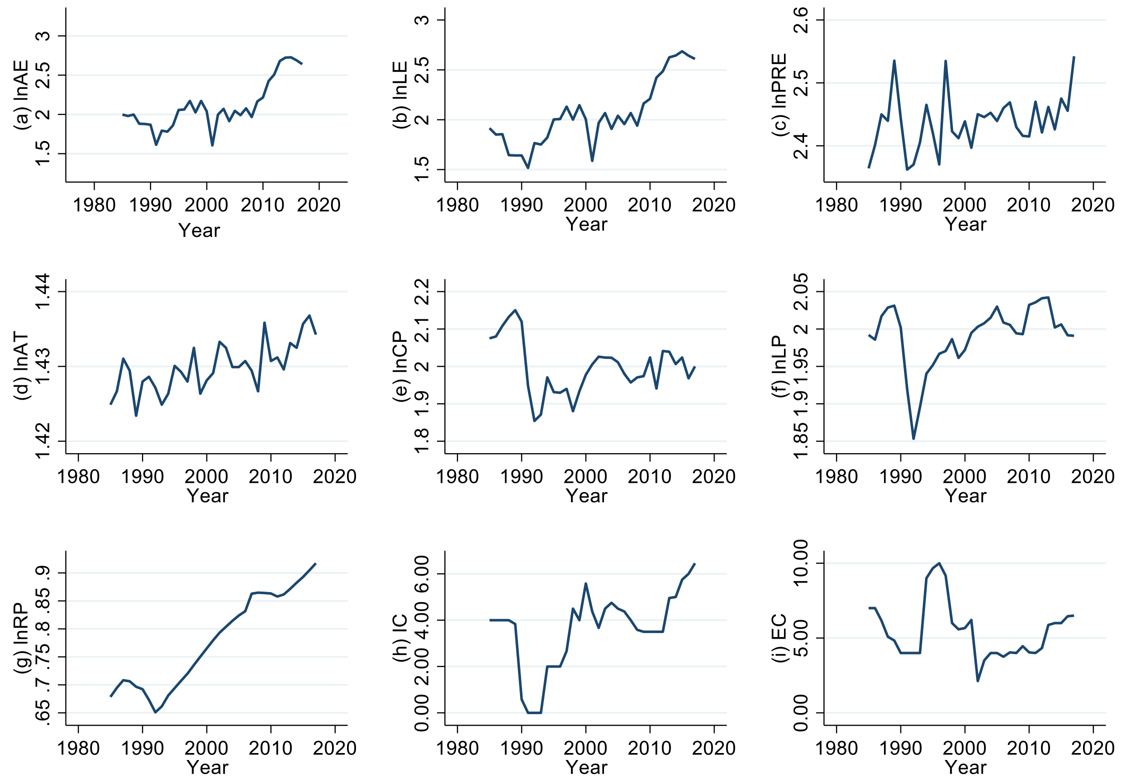

Figure 2. Trends of the sampled variables. (a) agricultural exports, (b) livestock exports, (c) average precipitation, (d) mean temperature, (e) crop production, (f) livestock production, (g) rural population, (h) internal conflicts, and (i) external conflicts.

Table 1. Variables, symbols, descriptions and sources.

Variable	Code	Description	Source
Dependent Variables			
Agricultural exports	AE	Export value (millions USD)	FAO
Livestock exports	LE	Export value (millions USD)	FAO
Climatic factors			
Average precipitation	PRE	Average annual precipitation (mm)	CCKP
Mean temperature	AT	Average annual temperature (°C)	CCKP
Non-climatic factors			
Crop production	CP	Crop production index (2014–2016 = 100)	WDI
Livestock production	LP	Livestock production index (2014–2016 = 100)	WDI
Rural population	RP	people living in rural areas (millions)	WDI
Internal conflicts	IC	The assessment rating comprises three elements: (a) the risk of civil war/coup, (b) terrorism/political violence, and (c) civil disorder.	ICRG
External conflicts	EC	The assessment rating consists of three elements: (a) armed conflict, (b) cross-border tensions, and (c) foreign influences.	ICRG

the availability of data for all variables. Detailed descriptions and data sources for the variables used in this study are presented in table 1, and the trends of these variables throughout the sample period are depicted in figure 2.

2.2. Econometric model specification

The formulation of the agricultural and livestock export model specifications used in this study followed the research of Chandio *et al* (2020, 2022), Pickson *et al* (2020), and Warsame *et al* (2022). Based on this, the initial segment of the study investigates the impacts of climatic factors, crop production, agricultural labor, and conflicts—internal and external—on agricultural exports in Somalia. On the other hand, the second segment of the study examines the influence of climate-related factors and conflicts on livestock exports in Somalia. It is noteworthy that we have converted the scrutinized variables, except internal and external conflicts, into natural logarithms to ensure data consistency, reduce variance, and interpret the results in percentage form. In Model I, the linear linkage among the variables is mathematically represented in equation (1) as follows:

$$\ln AE_t = \beta_0 + \beta_1 \ln PRE_t + \beta_2 \ln AT_t + \beta_3 \ln CP_t + \beta_4 \ln RP_t + \beta_5 IC_t + \beta_6 EC_t + \mathcal{E}_t \quad (1)$$

where $\ln AE_t$, $\ln PRE_t$, $\ln AT_t$, $\ln CP_t$, $\ln RP_t$, IC_t, and EC_t denote the natural logarithms of agricultural exports, average precipitation, mean temperature, crop production, rural population, internal and external conflicts in year t. In addition, $\mathcal{E}_t$ is the white noise error term in year t. In Model II, the linear relationship between the variables is described in equation (2) as follows:

$$\ln LE_t = \beta_0 + \beta_1 \ln PRE_t + \beta_2 \ln AT_t + \beta_3 \ln LP_t + \beta_4 \ln RP_t + \beta_5 IC_t + \beta_6 EC_t + \mathcal{E}_t \quad (2)$$

where $\ln LE_t$ and $\ln LP_t$ denote the natural logarithms of livestock exports and production, respectively.

In pursuit of the study objectives, we have adopted the ARDL approach introduced by Pesaran *et al* (2001) to investigate the long-run equilibrium association among the variables of interest. Unlike other cointegration techniques that necessitate all explanatory variables to be integrated in the same order, the ARDL method is applicable whether the variables are integrated in the same order or when the explanatory variables are integrated in various orders, i.e., I(0) or I(1). Besides, Ghatak and Siddiki (2001) suggest that the ARDL approach is statistically more robust when establishing the cointegration relationship, especially in cases with limited data samples. In addition, the ARDL method models long-run and short-run cointegration concurrently by considering coefficient asymmetric properties and bias-corrected bootstrapping for reliable statistical inferences on long-run cointegration among studied variables. Primarily, to investigate the existence of a long-run connection among the variables under investigation, we estimate the conditional ARDL model corresponding to equation (1) of Model I, which is articulated as follows:

$$\begin{aligned}\Delta \ln AE_t = {} & \alpha_0 + \alpha_1 \ln AE_{t-1} + \alpha_2 \ln PRE_{t-1} + \alpha_3 \ln AT_{t-1} + \alpha_4 \ln CP_{t-1} + \alpha_5 \ln RP_{t-1} + \alpha_6 IC_{t-1} \\ & + \alpha_7 EC_{t-1} + \sum_{i=1}^{p} \beta_1 \Delta \ln AE_{t-i} + \sum_{i=1}^{q} \beta_2 \Delta \ln PRE_{t-i} + \sum_{i=1}^{q} \beta_3 \Delta \ln AT_{t-i} \\ & + \sum_{i=1}^{q} \beta_4 \Delta \ln CP_{t-i} + \sum_{i=1}^{q} \beta_5 \Delta \ln RP_{t-i} + \sum_{i=1}^{q} \beta_6 \Delta IC_{t-i} + \sum_{i=1}^{q} \beta_7 \Delta EC_{t-i} + \varepsilon_t \end{aligned} \quad (3)$$

whereas α_0 represents the intercept, α_1—α_7 denotes the long-run coefficients, β_1—β_7 signifies the coefficients of the short-run variables, p and q indicates the variables optimal lag lengths, Δ represents for short-run parameters, and i symbolizes the lags. The conditional ARDL model representing equation (2) of Model II is derived as follows:

$$\begin{aligned}\Delta \ln LE_t = {} & \gamma_0 + \gamma_1 \ln LE_{t-1} + \gamma_2 \ln PRE_{t-1} + \gamma_3 \ln AT_{t-1} + \gamma_4 \ln LP_{t-1} \\ & + \gamma_5 \ln RP_{t-1} + \gamma_6 IC_{t-1} + \gamma_7 EC_{t-1} + \sum_{i=1}^{p} \delta_1 \Delta \ln LE_{t-i} + \sum_{i=1}^{q} \delta_2 \Delta \ln PRE_{t-i} \\ & + \sum_{i=1}^{q} \delta_3 \Delta \ln AT_{t-i} + \sum_{i=1}^{q} \delta_4 \Delta \ln LP_{t-i} + \sum_{i=1}^{q} \delta_5 \Delta \ln RP_{t-i} + \sum_{i=1}^{q} \delta_6 \Delta IC_{t-i} \\ & + \sum_{i=1}^{q} \delta_7 \Delta EC_{t-i} + \varepsilon_t \end{aligned} \quad (4)$$

whereas γ_0 represents the constant, γ_1—γ_7 stand for the long-run coefficients, δ_1—δ_7 demonstrate the coefficients of the short-run variables. Initially, we embrace the ordinary least squares (OLS) regression approach to analyze equation (3) in order to discover the long-run cointegration between the fundamental variables. In this context, the F-statistic of the bounds test is applied to assess the null hypothesis of no cointegration among the selected variables of Model I (H_0: $\alpha_1 = \alpha_2 = \alpha_3 = \alpha_4 = \alpha_5 = \alpha_6 = \alpha_7 = 0$) against the alternative hypothesis of cointegration linkage (H_1: $\alpha_1 \neq \alpha_2 \neq \alpha_3 = \alpha_4 \neq \alpha_5 \neq \alpha_6 \neq \alpha_7 \neq 0$). Moreover, the null hypothesis of no cointegration linkage for Model II (H_0: $\gamma_1 = \gamma_2 = \gamma_3 = \gamma_4 = \gamma_5 = \gamma_6 = \gamma_7 = 0$) is tested against the alternative hypothesis (H_1: $\gamma_1 \neq \gamma_2 \neq \gamma_3 \neq \gamma_4 \neq \gamma_5 \neq \gamma_6 \neq \gamma_7 \neq 0$). The bounds testing method relies on the Wald test, which is indicated by F-statistics. When the F-statistics value surpasses *I(1)*, it indicates the presence of long-run cointegration among the variables. Conversely, if the F-statistics value is lower than *I(0)*, it suggests the absence of cointegration between the variables. However, when the F-statistics value falls within the range of *I(0)* and *I (1)*, the results become uncertain. After conducting cointegration tests using equations (3) and (4), therror correction models (ECM) for short-run linkage among the regressors and the dependent variables are investigated. The symbols θ and η signify the coefficients associated with the error correction term (ECT). Equations (3) and (4) can be reformulated in the context of an error correction specification as follows:

Table 2. Descriptive summary and correlation analysis.

Panel A: Descriptive summary

	lnAE	lnLE	lnPRE	lnAT	lnCP	lnLP	lnRP	IC	EC
Mean	2.110	2.052	2.438	1.430	1.997	1.990	0.779	3.609	5.468
Maximum	2.727	2.686	2.542	1.437	2.150	2.042	0.917	6.458	10.000
Minimum	1.606	1.517	2.362	1.423	1.854	1.853	0.651	0.000	2.125
Std. Dev.	0.309	0.331	0.044	0.003	0.072	0.042	0.084	1.666	1.898
Skewness	0.749	0.544	0.514	0.219	0.204	−1.431	0.059	−0.807	0.873
Kurtosis	2.748	2.417	3.423	2.566	2.730	5.265	1.505	3.177	3.190
Jarque-Bera	3.169	2.092	1.700	0.523	0.330	18.314	3.092	3.624	4.239
Probability	0.205	0.351	0.427	0.770	0.848	0.000	0.213	0.163	0.120
Observations	33	33	33	33	33	33	33	33	33

Panel B: Correlation analysis

	lnAE	lnLE	lnPRE	lnAT	lnCP	lnLP	lnRP	IC	EC
lnAE	1.000								
lnLE	—	1.000							
lnPRE	0.383	0.337	1.000						
lnAT	0.645	0.668	0.209	1.000					
lnCP	0.035	—	0.264	−0.049	1.000				
lnLP	—	0.362	0.417	0.343	—	1.000			
lnRP	0.743	0.788	0.368	0.704	0.033	0.578	1.000		
IC	0.595	0.591	0.441	0.520	0.319	0.652	0.694	1.000	
EC	0.132	0.108	0.032	−0.087	−0.125	−0.199	−0.279	0.013	1.000

$$\Delta lnAE_t = \alpha_0 + \sum_{i=1}^{p} \beta_k \Delta lnAE_{t-i} + \sum_{i=1}^{q} \beta_k \Delta lnPRE_{t-i} + \sum_{i=1}^{q} \beta_k \Delta lnAT_{t-i} + \sum_{i=1}^{q} \beta_k \Delta lnCP_{t-i} + \sum_{i=1}^{q} \beta_k \Delta lnRP_{t-i} + \sum_{i=1}^{q} \beta_k \Delta IC_{t-i} + \sum_{i=1}^{q} \beta_k \Delta EC_{t-i} + \Delta ECT_{t-1} + \varepsilon_t \quad (5)$$

$$\Delta lnLE_t = \alpha_0 + \sum_{i=1}^{p} \delta_k \Delta lnLE_{t-i} + \sum_{i=1}^{q} \delta_k \Delta lnPRE_{t-i} + \sum_{i=1}^{q} \delta_k \Delta lnAT_{t-i} + \sum_{i=1}^{q} \delta_k \Delta lnLP_{t-i} + \sum_{i=1}^{q} \delta_k \Delta lnRP_{t-i} + \sum_{i=1}^{q} \delta_k \Delta IC_{t-i} + \sum_{i=1}^{q} \delta_k \Delta EC_{t-i} + \eta ECT_{t-1} + \varepsilon_t \quad (6)$$

3. Empirical results and discussion

3.1. Descriptive statistics

The descriptive summary and correlation analysis of the series are presented in table 2. In Panel A, the reported descriptive statistics summarize and present the main features of the datasets, including the central tendencies and variability. The mean values for the sample are as follows: agricultural exports (2.110), livestock exports (2.052), average precipitation (2.438), mean temperature (1.430), crop production (1.997), livestock production (1.990), and rural population (0.779). Moreover, external conflicts had a higher average value (5.468) than internal conflicts (3.609). It is noteworthy that external conflicts exhibit the highest maximum values, while internal conflicts display the lowest minimum values. Additionally, the external conflict variable stands out with the highest coefficient of variability of 1.898, implying that the individual data points are moderately dispersed for this series. However, average temperature (0.003), mean rainfall (0.044), and livestock production (0.042) had the least deviation from the mean. Also, the data distribution appears to be slightly right-skewed except for livestock production and internal conflicts. Based on the correlation analysis, which is summarized in Panel B, we measured the degree to which the movement of two different variables is associated. The sign of the correlation coefficient of all variables seems positive, which indicates that the variables have a favorable association with the dependent variables (agricultural and livestock exports). Moreover, the magnitude of the

Table 3. Unit root tests.

	ADF test		PP test	
Variables	Level	First difference	Level	First difference
lnAE	−0.921	−7.077[a]	−0.829	−7.059[a]
lnLE	−0.810	−7.215[a]	−0.663	−7.280[a]
lnPRE	−4.888[a]	−5.835[a]	−4.784[a]	−15.628[a]
lnAT	−3.403[b]	−8.184[a]	−3.344[b]	−20.449[a]
lnCP	−2.326	−5.149[a]	−2.262	−5.282[a]
lnLP	−1.872	−3.866[a]	−2.135	−3.645[b]
lnRP	0.549	−2.982[b]	0.125	−3.015[b]
IC	−1.142	−5.185[a]	−1.354	−5.185[a]
EC	−2.213	−5.220[a]	−2.321	−5.219[a]

The reported t-statistic is based on the constant only. [a], [b], and [c] represent the significance levels of 1%, 5%, and 10%, respectively.

Table 4. F-bounds test cointegration outcomes.

Model	F-statistic	Signif.	Bounds test critical values		Decision
			k = 6		
			I(0)	I(1)	
lnAE = *f*(lnPRE, lnAT, lnCP, lnRP, IC, EC)	8.798	1%	3.849	5.476	Cointegration
		5%	2.749	4.044	
		10%	2.284	3.428	
lnLE = *f*(lnPRE, lnAT, lnLP, lnRP, IC, EC)	19.969	1%	3.849	5.476	Cointegration
		5%	2.749	4.044	
		10%	2.284	3.428	

correlation coefficient indicates that the strength of the linkage among the data series is less than 0.8, which signals the absence of multicollinearity in the models.

3.2. Stationarity analysis

In the realm of time series modeling, it is a prerequisite to ascertain the stationarity properties of the series. To achieve this, the study utilized the Augmented Dickey-Fuller (ADF) and Philips Perron (PP) tests with the specification of an intercept to avoid spurious regression outcomes. The t-statistics of the ADF and PP tests presented in table 3 determine the integration orders at the 5% significance level. It was observed that only a few variables, namely average precipitation and temperature, appeared to be stationary at level I(0), which implies that these variables were stable over time. The rest of the series were non-stationary at I(0), although via the application of first differencing I(1), all of the variables transformed into stationary. The results in table 3 present mixed orders of integration, i.e., I(0) and I(1), while none of the variables exhibit stationarity at the second-difference I(2). Therefore, this affirms the applicability of ARDL for this analysis, as it can handle variables with various orders of stationarity.

3.3. Bounds cointegration test

Following the determination of the variables' integration order, the study uses the Krolzig and Hendry (2001) general-to-specific approach in the ARDL technique to select the most suitable lag length for the models. This approach addresses issues related to serial correlation and model stability by eliminating variables with the highest P-values until the error term is uncorrelated and parameters achieve stability. Given the limited number of observations in our dataset, the study initially considered two lags, which were later reduced to one. Subsequently, we investigated the presence of long-run cointegration between the dependent variable and the predictors. The bounds test results, as displayed in table 4, were grounded in the critical values established by Narayan (2005). It is evident from the Wald F-statistic of both export models—agricultural (8.798) and livestock (19.969)—that they surpass the upper bound critical value of 5.476 at the 1% significance level. As a result, this leads us to reject the null hypothesis of no long-run cointegration among the parameters. Thus, the outcome

Table 5. ARDL long-run elasticities.

	Model I (lnAE)		Model II (lnLE)	
Variable	Coefficient	t-statistic	Coefficient	t-statistic
lnPRE	3.859[b]	[2.969]	1.169[c]	[2.124]
lnAT	−8.370[a]	[−4.034]	−1.676	[−1.639]
lnCP	1.037[b]	[2.515]		
lnLP			−0.587	[−1.416]
lnRP	2.221[a]	[5.744]	2.321[a]	[9.799]
IC	−0.166[a]	[−6.115]	−0.129[a]	[−3.919]
EC	−0.028	[−1.619]	−0.024	[−1.648]

[a], [b], and [c] indicate 1%, 5%, and 10% significance levels, respectively. T-statistic is demonstrated in [...]. lnAE and lnLE signifies that the dependent variables are agricultural and livestock exports, respectively, for each model.

endorses the presence of a long-run equilibrium cointegration relationship among agricultural as well as livestock exports and the regressors under examination.

3.4. Long-run elasticities

After establishing the presence of long-run connections among the variables, we proceeded to estimate the long-run coefficients using the ARDL technique. As detailed in table 5, most of the explanatory variables seem to influence the various exports, such as agricultural and livestock, at the 1%, 5%, and 10% significance levels. The results unveil that average rainfall has a favorable linkage with both agricultural and livestock exports in the long-run. Specifically, a percentage increase in mean precipitation stimulates long-run agricultural and livestock exports in Somalia by approximately 3.85% and 1.16%, respectively. On the flip side, average temperatures exert a detrimental effect on long-run agricultural and livestock exports. Interpretively, an increase of 1% in mean temperature results in a substantial reduction of about 8.37% in agricultural exports at the 1% threshold level. While a percentage increase in temperature leads to a decrease in livestock exports by 1.67%, it was statistically insignificant. An intriguing result from the study indicates that crop production exerts a positive influence on the exports of agricultural products in the long-run. Thus, a 1% increase in crop yield stimulates the agricultural exports of Somalia by 1.03%. Albeit the negative effect of livestock production on livestock exports, it was not statistically different from zero. Additionally, the rural population exhibits a positive influence on long-run exports of agricultural products and livestock. Thus, a 1% rise in agricultural labor is associated with a 2.22% and 2.32% increase in agricultural and livestock exports, respectively, over the long-run. A striking outcome from the study indicates that incidents of internal conflicts reduce the various exports of Somalia in the long-run. Specifically, a 1 unit increase in internal conflicts inhibits agricultural and livestock exports by approximately 0.16% and 0.13%, respectively. Despite the negative effects of external conflicts on agricultural and livestock exports over the long-run, it was inconsequential as the p-values were not significant.

3.5. Short-run elasticities

On the other hand, the short-run findings of the two models are presented in table 6. While an increase in rainfall plays a constructive role in enhancing livestock exports, the average precipitation observed in the previous year has a detrimental and statistically significant effect on the current agricultural exports in the short-run. This suggests that a percentage change in average rainfall significantly enhances livestock exports by 1.02% in the short-run, although a 1% change in the previous year's rainfall is associated with a decrease in agricultural exports by approximately 1.08% at the 10% significance level. Besides, the current year's changes in mean temperature have a positive and significant influence on agricultural exports (27.98%) and livestock exports (15.94%) in the short-run. However, the previous average temperature value significantly stimulates only agricultural exports by 21.78%. Identically, a percentage change in the current year's crop production favorably raises agricultural exports by 0.88% in the short-run, although the influence of previous years was not statistically different from zero. However, the effects of the current year and previous years of livestock output are statistically insignificant in affecting livestock exports in the short-run. Despite the short-run estimates of the current year's changes in rural population enhances the exports of both agricultural and livestock, it presents statistically insignificant outcomes. However, the previous value of agricultural labor only inhibits the exports of agricultural products by 4.85% in the short-run. Remarkably, changes in the current year's internal conflicts significantly enhance only agricultural exports by 0.07%. In addition, changes in the previous year's external conflicts enhance livestock exports by 0.02%. However, it is essential to highlight that both the changes in the

Table 6. ARDL short-run elasticities.

	Model I (lnAE)		Model II (lnLE)	
Variable	Coefficient	t-statistic	Coefficient	t-statistic
Constant	0.440[a]	[3.645]	0.335[b]	[2.522]
$\Delta lnAE_{t-1}$	0.046	[0.266]		
$\Delta lnLE_{t-2}$			−0.123	[−0.775]
ΔlnPRE	0.897	[1.469]	1.021[c]	[1.716]
$\Delta lnPRE_{t-1}$	−1.087[c]	[−2.043]	−0.768	[−1.335]
ΔlnAT	27.983[a]	[3.112]	15.949[b]	[2.275]
$\Delta lnAT_{t-1}$	14.453	[1.569]		
$\Delta lnAT_{t-2}$	21.788[b]	[2.252]	7.852	[0.956]
ΔlnCP	0.885[c]	[1.821]		
$\Delta lnCP_{t-2}$	0.591	[1.132]		
ΔlnLP			−0.97	[−0.813]
$\Delta lnLP_{t-2}$			1.314	[1.536]
ΔlnRP	1.291	[0.517]	2.348	[0.842]
$\Delta lnRP_{t-2}$	−4.859[c]	[−1.91]		
ΔIC_{t-1}	0.075[b]	[2.450]	0.052	[1.597]
ΔIC_{t-2}			−0.022	[−0.623]
ΔEC	−0.03	[−1.627]	−0.007	[−0.436]
ΔEC_{t-2}	0.02	[1.307]	0.029[c]	[1.883]
ECT_{t-1}	−0.258[a]	[−3.287]	−0.218[b]	[−2.467]

Δ = differencing.

previous lags of internal conflicts and the current year's external conflicts do not exhibit statistical significance in the short-run for both agricultural and livestock exports. Of particular significance is the error correction term (ECT), which explains the rate of adjustment towards long-run equilibrium following short-run deviations in agricultural and livestock exports. The ECT holds statistical significance and a negative coefficient, signifying that short-run deviations in agricultural and livestock exports will be corrected by the relevant explanatory variables by approximately 0.25% and 0.21%, respectively, each year.

The study's findings align with previous research, such as Khan *et al* (2019) and Dallmann (2019), confirming that extreme weather events reduce agricultural exports. In line with our results, (Chen *et al* 2017) noted that temperature increases and declining rainfall reduce crop output. It is very common in Somalia that farming practices predominantly rely on natural rainfall for irrigation and moisture without significant dependence on artificial irrigation systems. Dissimilar to our results, Attiaoui and Boufateh (2019) found that changes in precipitation may lead to a steady decline in crop yield. This suggests that intense rainfall presents a substantial risk to agricultural productivity, which might lead to waterlogging, soil erosion, and disruption of planting and harvesting schedules. Compared to other industries, such as manufacturing and raw materials, Jones and Olken (2010) supported our finding that temperature has significant detrimental effects on exports of agricultural products. Other studies, including Abbas (2022) and Abdi *et al* (2023), asserted that temperature changes may lead to a consistent decline in crop yield. In Somalia, due to the increasing temperature, there are water shortage issues, inducing heat stress in plants that disrupt traditional agricultural seasons. Ultimately, this affects crop planting times and harvesting as well as exports. On the other hand, Nardone *et al* (2010) and Ayanlade and Ojebisi (2019) found that drought conditions could significantly impact crop and fodder production, thereby threatening livestock productivity. Using similar econometric approaches, Warsame *et al* (2022) reinforce our findings that adverse climatic conditions reduce livestock production as well as exports. These findings are consistent with our results that climatic factors undermine agricultural and livestock exports.

Our findings indicate that increased crop production in Somalia enhances agricultural exports. This highlights that when a country experiences higher yields in crop production, it often leads to a greater quantity of crops available for both domestic consumption and export. Besides, our results unveil that rising livestock production bolsters livestock exports by generating a surplus supply of animals and related products. This fosters economic growth by establishing a competitive advantage, creating employment opportunities, and contributing to foreign exchange earnings. Moreover, the study's outcome that rural populations enhance agricultural and livestock exports is in line with Abdi *et al* (2023) and Chandio *et al* (2021), who arrived at similar conclusions. However, it contradicts Ali Warsame and Hassan Abdi (2023), who found that rural populations negatively contribute to agricultural output in Somalia. A striking result from our findings indicates that internal and external conflicts hamper agricultural and livestock exports in Somalia, although external conflicts are inconsequential. This asserts that extreme weather events and unpredictable seasonal rainfalls might jeopardize

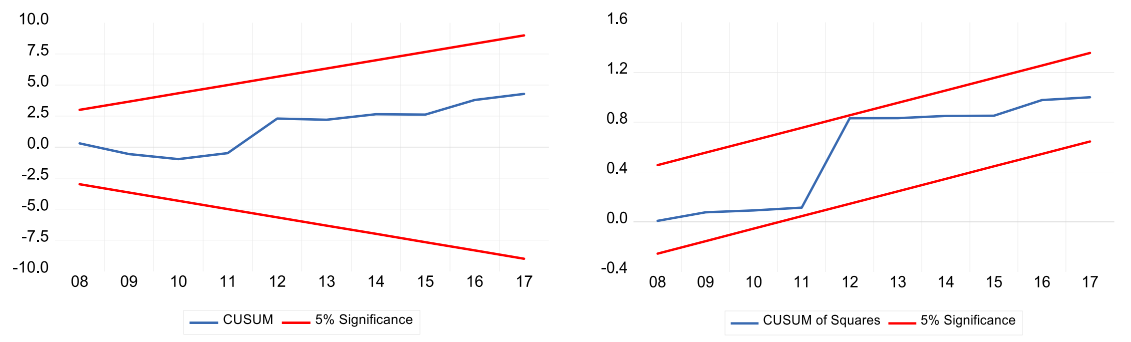

Figure 3. CUSUM and CUSUM of Squares for Model I (lnAE).

Table 7. Results of diagnostic tests.

Test type	Model I (lnAE)	Model II (lnLE)
R-Squared	0.773	0.891
Serial Correlation—LM test	0.468	2.419
	[0.493]	[0.119]
Heteroskedasticity—BPG test	21.604	21.368
	[0.362]	[0.436]
Normality—JB test	0.391	0.141
	[0.822]	[0.932]
Ramsey RESET Test	1.322	1.748
	[0.219]	[0.119]

agropastoralism's availability of pasture and water (SPIRI, 2023). Internal conflicts in Somalia have hindered the country's ability to participate in international trade through its local ports, such as Mogadishu and Kismayo, which were partially closed during the first two decades of the conflicts. This has led to the use of neighboring countries' ports as well as indirect export routes, which were from Somalia to Djibouti and Yemen and then to the destination countries in the Arabian Peninsula (Mtimet *et al* 2021). Amid the country's civil unrest, the renewed import ban by Saudi Arabia reduced the volume of livestock exports in 2016 and 2017 (World Bank & FAO, 2018).

3.6. Diagnostic tests

In our quest for unbiased and reliable results, we meticulously conducted a series of diagnostic tests, as displayed in table 7. The empirical results from these tests affirm that our model successfully passes these diagnostic checks. Specifically, the data follows a normal distribution, and there is no evidence of serial correlation, heteroskedasticity, or misspecification of the functional form. The models' goodness of fit is notably robust, with an R-squared value of 0.77 for Model I and 0.89 for Model II. This implies that 77% and 89% of the variations observed in agricultural and livestock exports can be attributed to the variables under examination, which include average precipitation, mean temperature, crop and livestock production, rural population, internal and external conflicts. Besides, it is crucial to note that the models employed in the study demonstrate stability through the examination of CUSUM and CUSUM of square tests, as depicted in figures 3 and 4. These stability tests provide further assurance that the models' parameters remain consistent and reliable for analytical purposes.

3.7. Sensitivity analysis

The outcomes of our robustness tests for Models I and II, conducted as a supplement to the ARDL long-run estimates, are presented in table 8. The results obtained from the FMOLS analysis offer robust confirmation of the long-run effects of climatic factors and conflicts on agricultural and livestock exports within the context of Somalia. The outcomes of this sensitivity analysis demonstrated a consistent alignment in both the sign and significance of the coefficients with the estimates derived from the ARDL model. Remarkably, it is evident that average rainfall and agricultural labor have positive effects on both agricultural exports, while mean temperature and crop/livestock production inhibit them. Albeit we found that internal and external conflicts hamper

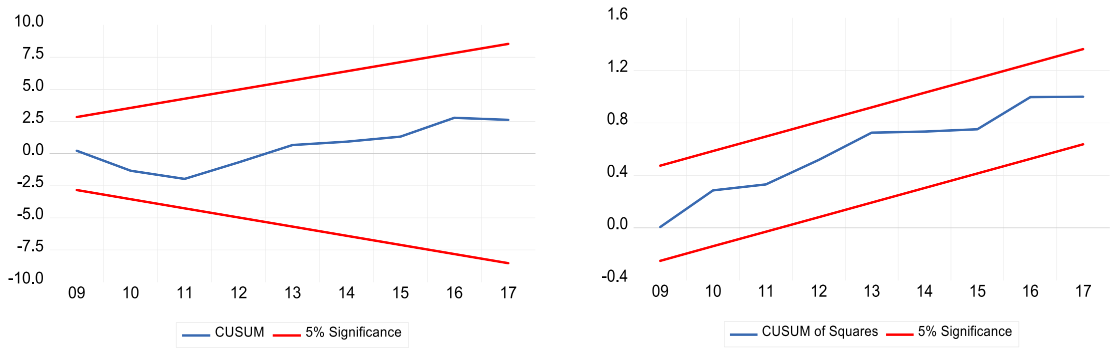

Figure 4. CUSUM and CUSUM of Squares for Model II (lnLE).

Table 8. FMOLS long-run estimates.

	Model I (lnAE)		Model II (lnLE)	
Variable	Coefficient	t-statistic	Coefficient	t-statistic
lnPRE	5.177[a]	[42.031]	0.856[a]	[6.854]
lnAT	−4.894[a]	[−22.931]	−0.183	[−0.706]
lnCP	−2.998[a]	[−40.405]		
lnLP			−1.329[a]	[−8.548]
lnRP	3.167[a]	[34.586]	3.208[a]	[36.297]
IC	−0.016[a]	[−3.496]	0.028[a]	[5.975]
EC	−0.004	[−1.419]	0.051[a]	[19.004]

agricultural exports, they stimulate the exports of livestock. These FMOLS results serve as strong corroborative evidence, reinforcing and verifying the long-run findings obtained through the ARDL approach. These findings serve as a valuable foundation for informed policy decisions aimed at promoting various exports in Somalia.

3.8. Granger causality analysis

While the various cointegration techniques, such as ARDL and FMOLS, have limitations in detecting causality, we extended the investigation to Granger causation among the variables under scrutiny. The causality results of Model I (agricultural exports) and Model II (livestock exports) are presented in table 9. For Model I, we fail to reject the null hypothesis that average rainfall and temperature Granger cause agricultural exports. However, the results reveal causality flows unidirectionally from agricultural exports to average precipitation and temperature variations. In this context, agricultural exports cause precipitation and temperature, but the reverse does not hold true—climatic factors do not significantly cause agricultural exports. Moreover, there is no observed causality identified between crop production and agricultural exports, as well as external conflicts and agricultural exports. Additionally, the analysis demonstrates that agricultural labor Granger causes agricultural exports. This can be attributed to the fact that an expansion in agricultural labor tends to boost agricultural production and exports. The Granger causality analysis demonstrated the presence of a one-way causality from agricultural exports to internal conflicts. Moreover, this finding aligns with the previous study of Crost and Felter (2020), who demonstrated that the rise in the value of bananas, which is the primary export crop of the Philippines, induces the escalation of civil unrest and the expansion of insurgent-controlled areas. For Model II, we did not detect any causal linkage between average rainfall and livestock exports. Moreover, there is a one-way causality from livestock exports to average temperature, indicating that livestock exports have the possibility of causing anomalies in temperature. However, the study reveals no evidence of a causal association between livestock production and livestock exports, as well as external conflicts and livestock exports. A noteworthy discovery of the analysis revealed a bidirectional causality between agricultural labor and livestock exports. Agricultural labor, which is measured as rural population, plays a pivotal role in livestock herding in Somalia. The growth of the rural population leads to an increase in livestock production and exports, since they account for 52.68% of the total population (World Bank 2022).

Table 9. Granger causality outcomes.

H_0: no granger causation			F-statistic	Direction of causality
Panel A: Agricultural exports model				
lnPRE	≠	lnAE	2.029	Unidirectional
lnAE	≠	lnPRE	3.081[c]	
lnAT	≠	lnAE	0.661	Unidirectional
lnAE	≠	lnAT	7.231[b]	
lnCP	≠	lnAE	0.726	No causation
lnAE	≠	lnCP	0.355	
lnRP	≠	lnAE	3.365[c]	Unidirectional
lnAE	≠	lnRP	1.299	
IC	≠	lnAE	0.137	Unidirectional
lnAE	≠	IC	9.055[a]	
EC	≠	lnAE	0.000	No causation
lnAE	≠	EC	0.727	
Panel B: Livestock exports model				
lnPRE	≠	lnLE	2.229	No causation
lnLE	≠	lnPRE	2.505	
lnAT	≠	lnLE	0.576	Unidirectional
lnLE	≠	lnAT	8.501[a]	
lnLP	≠	lnLE	0.017	No causation
lnLE	≠	lnLP	1.369	
lnRP	≠	lnLE	3.204[c]	Bidirectional
lnLE	≠	lnRP	4.421[b]	
IC	≠	lnLE	0.939	Unidirectional
lnLE	≠	IC	13.829[a]	
EC	≠	lnLE	0.061	No causation
lnLE	≠	EC	0.867	

≠ indicates the null hypothesis of no causal linkage among the two variables.

4. Conclusion and policy implications

In Somalia, escalating temperatures, erratic precipitation patterns, and internal strife have disrupted traditional farming practices, leading to decreased crop yields and hampered livestock production, thereby challenging the nation's ability to sustain exports. It is necessary to highlight the need for customized interventions to enhance resilience and sustainable practices in the agricultural and livestock sectors. Hence, this research examines the intricate effects of climate change and conflicts—internal and external—on agricultural and livestock exports in Somalia over the period 1985–2017. The order of integration of the variables in question was ascertained using the ADF and PP tests in order to prevent misleading regression; the results showed a mixed order of integration, i.e., I(0) and I(1). In order to investigate the long-run relationship and causal linkage of the variables, this endeavor used the ARDL technique, the FMOLS approach, and the Granger causality test. Both the model stability tests and all diagnostic tests were passed by the model. Notably, the findings of the study indicate that average rainfall emerges as a positive driver for both short- and long-run agricultural and livestock exports, while average temperature exhibits a detrimental effect on long-run agricultural exports. The study emphasizes the significance of crop production in agricultural exports, even though livestock production was found to be statistically insignificant. The surge in rural population was identified as a contributing factor to increased agricultural and livestock exports in the short- and long-run. Intriguingly, internal and external conflicts were discovered to have adverse effects on crop and animal exports in the long-run, with external conflicts being statistically insignificant. The causality analyses revealed a unidirectional causation from agricultural exports to precipitation, temperature fluctuations, and internal conflicts. Additionally, the study underscores the bidirectional causality of agricultural labor with agricultural and livestock exports.

In response to the formidable challenges posed by climate change and conflicts over agricultural and livestock exports in Somalia, strategic policy measures are imperative. In regard to the findings of the study, policymakers should prioritize the following areas. Firstly, Somalia should broaden the range of products it exports by leveraging the existing trade structures instead of relying heavily on a limited set of agricultural and livestock exports. Diversification reduces the country's vulnerability to fluctuations in the market for specific goods, minimizes risks associated with climate-related and conflict-induced disruptions, and enhances overall economic resilience. Secondly, as internal conflicts disrupt farming operations, leading to displacement of rural communities and destruction of infrastructure, peacebuilding measures, such as conflict resolution, social reconciliation, and inclusive governance, contribute to the creation of a conducive atmosphere for farmers to cultivate their land and raise livestock without the constant threat of violence or disruption. Thirdly, the authorities should foster sustainable land management practices, facilitate market access, and invest in research and capacity building to ensure a holistic and effective response to the complex challenges of climate change and conflicts in the agricultural and livestock sectors in Somalia. Finally, measures need to be taken to mitigate the impact of climate change on agriculture, such as investing in resilient farming systems, promoting sustainable agricultural practices, and supporting farmers in adapting to changing climatic conditions. Ultimately, the implementation of these strategies is paramount to fostering sustainable development and resilience in the face of a changing climate and geopolitical landscape.

Data availability statement

The data that support the findings of this study are openly available at the following URL/DOI: https://doi.org/https://www.fao.org/faostat/en/#data.

Declarations

Ethical approval

This study follows all ethical practices during writing. We declare that this manuscript is original, has not been published before and is not currently being considered for publication elsewhere.

Author contributions

Abdikafi Hassan Abdi: Conceptualization, methodology, data collection and analyzing, writing, improving and editing the original draft. Abdisalan Aden Mohamed: the literature review. Mohamed Okash Sugow: edited the whole manuscript. Dhaqane Roble Halane: some parts of the introduction.

Consent to participate

Not applicable.

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.

Data availability

The datasets used and/or analyzed during the current study are available from the author on reasonable request.

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