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An integrated approach to sustainable food production systems: a case study of Somalia

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ABSTRACT

Food production serves as a vital foundation for food security, economic stability, and social well-being, especially in fragile and low-income settings such as Somalia. Although agricultural activities continue to be fundamental to food production, structural determinants—such as income inequality, institutional quality, industrialization, and fisher captures—play a significant role in influencing long-term productivity outcomes. This research investigates the combined impact of capture fisheries output, income disparity, institutional governance, and industrial development on food production in Somalia, employing annual data from 1991 to 2020). The analysis adopts a log-linear specification and applies the ARDL bounds testing approach, DOLS, and Granger causality techniques. The analysed data reveal that captures fisheries, industrial growth, and institutional quality exert positive and statistically significant effects on food production, but income disparity has a significantly adverse impact. Granger causality results further reveal important feedback relationships between food production, governance, and industrial development. These findings emphasize the importance of integrating marine resource utilization, industrial development, and institutional governance within a comprehensive food production system in Somalia. The findings provide important insights for strengthening sustainable and integrated food production systems in Somalia through improved fisheries management, agro-industrial development, institutional capacity building, and inclusive strategies to reduce inequality.

IMPACT STATEMENT

This study sheds light on the factors shaping food production in Somalia, with particular attention to the roles of fisheries, industrial development, governance, and income inequality. The findings suggest that improving institutional effectiveness and strengthening productive sectors can support more stable and sustainable food systems, while persistent inequality continues to constrain productive capacity and rural livelihoods. By bringing together agricultural and fisheries perspectives, the study offers a broader understanding of how different sectors interact within Somalia's food production system. The results may also provide useful insights for policymakers and researchers working on food security and structural transformation in other fragile and low-income African economies facing similar challenges.

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Economics; Industry and Industrial Studies; Sustainable Development

1. Introduction

Food production serves as a crucial factor influencing food security, economic stability, and social welfare, especially in low-income and fragile economies where agriculture and associated sectors sustain the livelihoods of a significant portion of the population (Abdi et al., 2024; Abdi, Ahmed, et al., 2025). Despite advancements in global food production, numerous developing and conflict-affected nations persistently face food insecurity, attributable to structural constraints that surpass mere agricultural inputs. In recent years, the literature has increasingly emphasized that food production outcomes are shaped not only by land, labor, and climatic conditions, but also by broader economic and institutional

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environments. In particular, income distribution, governance quality, and the degree of economic diversification into sectors such as fisheries and manufacturing have emerged as critical determinants of productivity and sustainability (Fanzo et al., 2020; Timmer, 2017). In fragile states, these structural challenges tend to be more pronounced, as weak governance systems, persistent inequality, and limited diversification constrain productive capacity while simultaneously increasing vulnerability to environmental shocks and economic disruptions (Barrett, 2021; FAO et al., 2021). Over time, therefore, food systems have evolved from a narrow focus on agricultural production toward more integrated frameworks that incorporate structural, institutional, and sustainability dimensions, reflecting a growing recognition of the complex and interconnected nature of food production processes.

Theoretical frameworks on structural transformation provide an important foundation for understanding these dynamics. Classical dual-economy models suggest that reallocating labor from low-productivity agricultural sectors to more productive non-farm activities can stimulate economic growth and indirectly enhance agricultural productivity through demand linkages, technological diffusion, and income effects (Johnston & Mellor, 1961; Lewis, 1994). However, the extent to which these mechanisms translate into improved food production depends critically on institutional conditions and the distribution of economic gains. Empirical studies demonstrate that where institutional quality is weak and income inequality is high, structural transformation may fail to reinforce agricultural productivity and may instead exacerbate existing disparities (Anderson et al., 2019; Dorward et al., 2004). In such contexts, diversification can marginalize agriculture rather than support it, thereby weakening food production systems and intensifying food insecurity (Gollin et al., 2002; Rodrik, 2000). Accordingly, food production is increasingly conceptualized within a multidimensional framework that integrates economic structure, governance, and distributional dynamics (Fanzo et al., 2020). This perspective aligns with emerging food systems approaches, which emphasize the interconnected roles of production processes, institutional arrangements, and broader economic transformations in shaping food outcomes.

Within this wider context, capture fisheries production has emerged as a vital yet underrecognized component of national food systems. Fisheries constitute a crucial source of animal protein and indispensable micronutrients for billions of people worldwide, especially in coastal and low-income countries where land-based agriculture is inadequate to meet dietary needs (FAO, 2020; Golden et al., 2016). Capture fisheries situates fisheries within a comprehensive economic framework that promotes food security, employment, and inclusive development, provided that sustainable management practices are implemented (Béné et al., 2015; OECD, 2016). Empirical research demonstrates that fisheries production directly contributes to food security and indirectly promotes income generation, diversification of livelihoods, and resilience to agricultural disturbances (Béné et al., 2016; Hicks et al., 2019). These benefits are contingent upon the quality of governance, as inadequate regulation and overexploitation may compromise long-term productivity and food security (Pauly & Zeller, 2016; World Bank, 2017). Although there is increasing acknowledgment of the relationship between fisheries and food security, the majority of empirical models concerning food production predominantly concentrate on terrestrial agriculture, thereby omitting aquatic food sources from national food production assessments. This omission is especially significant for coastal fragile states that possess considerable marine resources. Somalia has one of the longest coastlines in Africa and considerable fisheries potential; however, the contribution of capture fisheries to national food production is inadequately quantified. Recent research on Somalia's fisheries sector predominantly adopts a descriptive approach, focusing on issues including illegal, unreported, and unregulated fishing, inadequate governance structures, and untapped economic potential. Nonetheless, these contributions offer restricted empirical evidence regarding the impact of fisheries output on national food production outcomes (FAO, 2020; World Bank, 2017).

Income inequality constitutes a key structural factor affecting both food production and food security. Extensive research indicates that rising inequality reduces agricultural productivity by limiting access to land, credit, and productive technologies for small-scale and marginalized producers (Carter & Barrett, 2013; Deininger & Squire, 1998). Furthermore, cross-national studies show that inequality erodes the growth-enhancing and poverty-reducing benefits of agricultural expansion, particularly in developing economies characterized by significant market imperfections (Alesina & Rodrik, 1994; Ravallion, 2018). Inequality diminishes effective demand and hinders the translation of increased food production into enhanced nutrition and food access for at-risk populations (FAO et al., 2021; Headey & Alderman, 2019). The dynamics are particularly evident in fragile states, where inequality intersects with conflict,

environmental stress, and institutional weakness, thereby intensifying food insecurity (Barrett, 2021; Persson & Tabellini, 2002). Research on food security in Somalia has primarily concentrated on drought, conflict, displacement, and humanitarian conditions, providing an insufficient understanding of the structural factors influencing food production (FAO et al., 2021; World Bank, 2021). Although these studies are crucial for comprehending immediate food access challenges, they fail to integrate income inequality indicators, such as the Gini coefficient, into analyses of national food production performance.

Institutional quality and industrialization significantly affect food production by determining incentives, the efficiency of public investment, and the organization of economic activities. Effective institutions, characterized by government performance, regulatory standards, and accountability, contribute to agricultural productivity by minimizing transaction costs, safeguarding property rights, and enhancing service delivery (Kaufmann et al., 2011; North, 1990). Empirical research consistently demonstrates a correlation between improved governance and enhanced agricultural productivity, as well as more resilient food systems (Fuglie et al., 2019; Rodrik, 2000). Industrialization can enhance food production through the creation of non-farm employment, increased demand for agricultural products, and the promotion of technological spillovers, contingent upon supportive institutional frameworks for balanced development (Szirmai, 2012; Timmer, 2017). In contrast, premature or inadequately managed industrialization can displace agriculture and diminish food production capacity (Gollin et al., 2014; Rodrik, 2016). Research in Somalia has predominantly focused on state-building, conflict dynamics, and the effectiveness of aid, with less emphasis on the performance of food production (World Bank, 2021). Research in agribusiness and value chains predominantly emphasizes micro-level outcomes, including household income and resilience, while neglecting the incorporation of institutional quality and industrialization within national food production frameworks. Taken together, these interrelated factors highlight the importance of examining food production within an integrated framework that captures the interactions between economic structure, institutional quality, and distributional conditions.

Despite these theoretical and empirical insights, research on Somalia's food systems remains limited in scope. Existing studies have predominantly focused on climate shocks, drought, conflict, displacement, and humanitarian responses, with comparatively little attention given to structural determinants of food production. In particular, the combined roles of capture fisheries, income inequality, institutional quality, and industrialization have not been systematically examined within a single empirical framework. This gap is especially important given Somalia's unique characteristics, including its extensive coastline, significant but underutilized marine resources, fragile institutional environment, persistent inequality, and limited structural transformation. These conditions make Somalia a particularly relevant case for examining food production through an integrated analytical lens. The current study addresses this gap by providing a Somalia-specific time-series analysis of food production that simultaneously incorporates capture fisheries output, income inequality, institutional quality, and industrialization. By integrating these dimensions within a unified empirical framework, the study contributes to the growing literature on food production systems and offers new evidence on the structural drivers of food production in fragile economies. More specifically, the study aims to examine how these factors influence food production in Somalia in both the short run and the long run, thereby providing a more comprehensive understanding of how different components of the food system interact and evolve over time.

Guided by the theoretical framework and the empirical literature reviewed earlier, this study establishes a set of expectations regarding the key factors influencing food production in Somalia. Capture fisheries are expected to positively affect food production due to their contribution to food supply, livelihood generation, and improved nutritional outcomes, particularly in coastal and resource-dependent environments (Béné et al., 2016; Hicks et al., 2019), as emphasized in food systems and nutrition-based frameworks, which highlight the role of aquatic resources in enhancing food availability and dietary diversity. In contrast, income inequality is anticipated to have an adverse effect by restricting access to productive assets, reducing investment opportunities, and weakening inclusive growth patterns (Carter & Barrett, 2013; Ravallion, 2018), consistent with inequality-productivity theory, which posits that unequal resource distribution reduces productive efficiency and limits output growth. Institutional quality is also expected to influence food production positively, as stronger governance systems can enhance efficiency in resource allocation, improve policy effectiveness, and support productivity growth (Fuglie et al., 2019; Rodrik, 2000), in line with institutional economics theory, where governance structures shape economic performance and resource allocation outcomes. Moreover, industrialization is likely to strengthen food

production through its role in advancing value chains, encouraging technological innovation, and promoting structural economic transformation (Szirmai, 2012; Timmer, 2017), as predicted by structural transformation theory, which links sectoral shifts and industrial development to productivity improvements in agriculture and related sectors. Consistent with these expectations, the study evaluates the following hypotheses: H1: capture fisheries positively influence food production; H2: income inequality negatively influences food production; H3: institutional quality positively influences food production; and H4: industrialization positively influences food production in Somalia.

The conceptual framework in Figure 1 presents the hypothesized causal relationships between the explanatory variables and food production. Capture fisheries, institutional quality, and industrialization

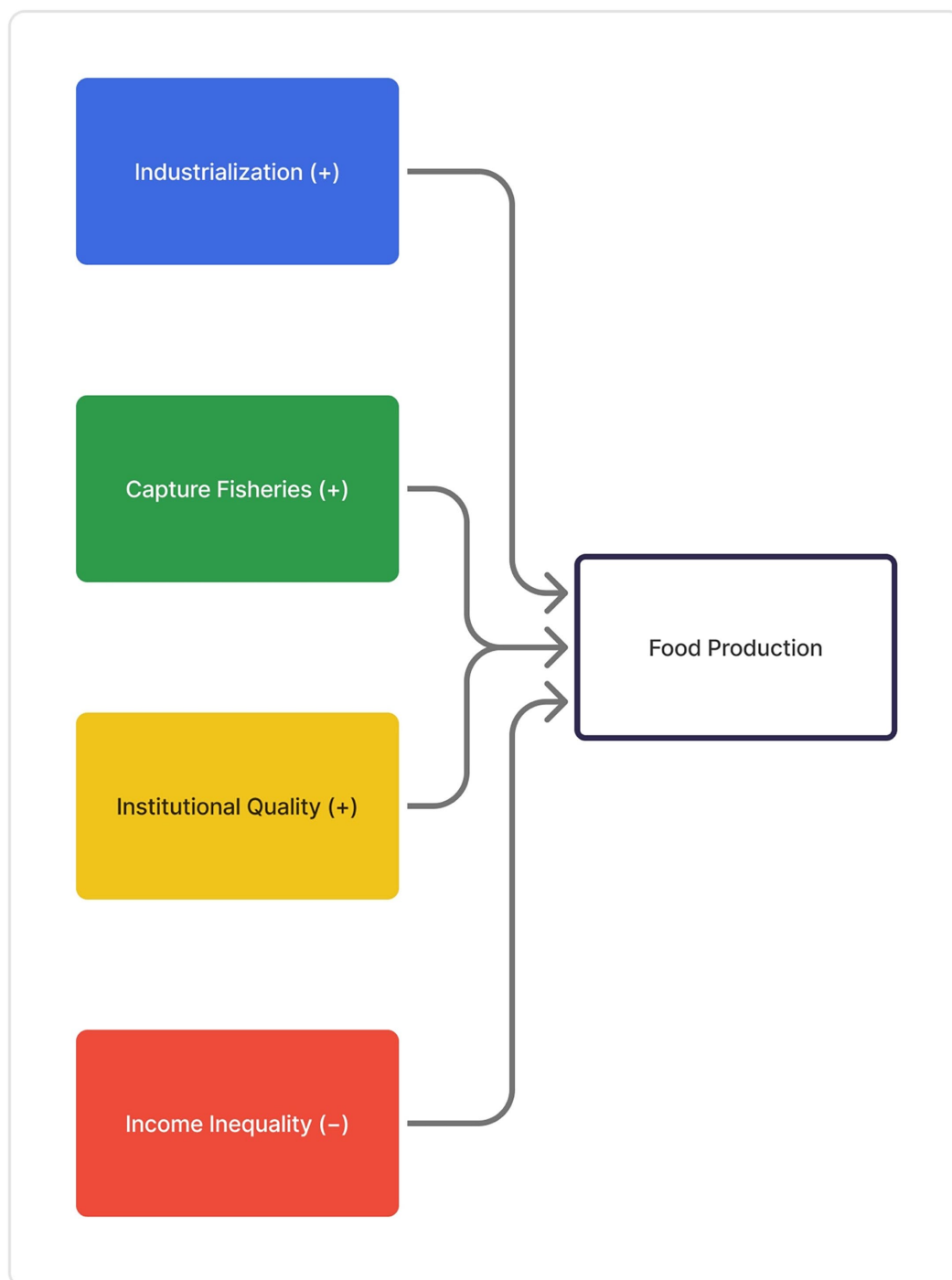


Figure 1. Conceptual framework of the study.

are expected to exert positive effects on food production, while income inequality is expected to have a negative effect. The directional arrows represent the causal pathways tested in the empirical model, consistent with the theoretical foundations and prior empirical evidence discussed in the study.

The remainder of the paper is organized as follows. [Section 2](#) presents the data and methodology. [Section 3](#) reports and discusses the empirical results. [Section 4](#) concludes and offers policy implications.

2. Data and methods

Drawing on annual data from 1991 to 2020, this study adopts a quantitative time-series research design to examine the principal determinants of food production in Somalia, serving as an indicator of both agricultural performance and national food security. This period is selected due to the structural break in 1991 following state collapse and the availability of consistent data for all variables from the early 1990s onward. The analysis emphasizes the influence of capture fisheries, income distribution, institutional quality, and industrialization on the long-term sustainability of agricultural output. The empirical strategy follows a structured sequence of econometric procedures, as illustrated in [Figure 2](#).

The measurement of food production utilizes the Food Production Index (2014–2016=100) sourced from the World Development Indicators (WDI). This index reflects variations in agricultural output in relation to a base period, while also considering inflationary factors. Moreover, capture fisheries production reflects the country's utilization of marine and coastal resources and its contribution to overall food production and food availability. The Gini coefficient, derived from the World Income Inequality Database (WIID), quantifies income inequality, highlighting disparities that can influence access to resources, inputs, and markets. The measure of institutional quality, derived from the International Country Risk Guide (ICRG), reflects the efficacy of governance frameworks in executing policies and delivering public

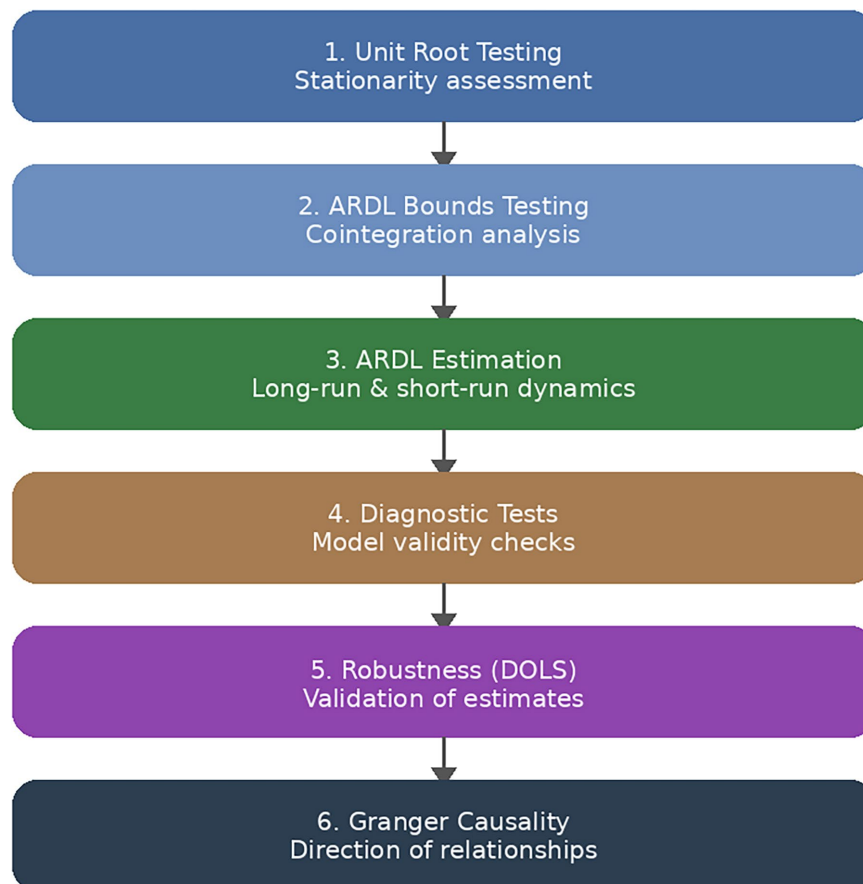


Figure 2. Empirical strategy and econometric procedure of the study.

Notes: ARDL: autoregressive distributed lag; DOLS: dynamic ordinary least squares.

Source: Author's illustration.

Table 1. Data and variables description.

Variable	Symbol	Measurement	Source
Explained variable			
Food production	Lnfpi	Food production index (2014–2016=100)	WDI
Explanatory variable			
Capture fisheries	Lncf	Capture fisheries production (metric tons)	WDI
Income inequality	Lngini	Gini coefficient index	WIID
Institutional quality	Lniq	Government effectiveness	ICRG
Industrialization	Lnind	Manufacturing, value added, constant 2015 prices	SESRIC

services. Industrialization, represented by manufacturing value added from SESRIC in constant 2015 prices, indicates economic diversification, which has the potential to foster technological advancement and compete with agriculture for resources. The study variables are summarized in Table 1, detailing their symbols, definitions, and data sources.

2.1. Model specification

Based on theoretical perspectives and empirical evidence from previous studies (Abdi, Khalif, et al., 2025; Abdi, Mohamed, Halane, et al., 2025), this study enhances the analysis of food production through a log-linear specification that reflects the complex and interconnected influences of its primary determinants. By implementing the food production index, the study quantifies variations in agricultural output over time while offering a detailed framework for comprehending how economic and institutional factors together influence the path of agricultural sustainability. The log-linear specification is employed to stabilize variance, reduce potential heteroskedasticity, and allow the estimated coefficients to be interpreted as elasticities, thereby providing meaningful insights into the responsiveness of food production to its determinants.

$$\ln fpi_t = \vartheta_0 + \vartheta_1 \ln cf_t + \vartheta_2 \ln gini_t + \vartheta_3 \ln iq_t + \vartheta_4 \ln ind_t + \mu_t \quad (1)$$

Within this analytical paradigm, fpi represents food production, cf represents the contributions of fisher captures, $gini$ measures income inequality, iq indicates institutional quality, and ind is a proxy for industrialization. The coefficients ϑ_1 through ϑ_4 represent the elasticities of food production with respect to each explanatory variable. The stochastic error term μ_t is supposed to follow a white-noise process, capturing unobserved shocks and random disturbances in the model.

Expanding upon Equation (1), the ARDL model that encompasses both long-term and short-term dynamics may be expressed as follows:

$$\begin{aligned} \Delta \ln fpi_t = & \vartheta_0 + \vartheta_1 \ln fpi_{t-1} + \vartheta_2 \ln cf_{t-1} + \vartheta_3 \ln gini_{t-1} + \vartheta_4 \ln iq_{t-1} + \vartheta_5 \ln ind_{t-1} + \sum_{i=1}^p \phi_1 \Delta \ln fpi_{t-i} \\ & + \sum_{i=1}^p \phi_2 \Delta \ln cf_{t-i} + \sum_{i=1}^q \phi_3 \Delta \ln gini_{t-i} + \sum_{i=1}^q \phi_4 \Delta \ln iq_{t-i} + \sum_{i=1}^q \phi_5 \Delta \ln ind_{t-i} + \eta EC_{t-1} + \varepsilon_t \end{aligned} \quad (2)$$

In this model, ϑ_0 denotes the intercept, while the coefficients ϑ_1 to ϑ_5 represent the long-term elasticities, indicating the enduring relationships among the variables. In the interim, ϕ_1 to ϕ_5 illustrate short-term adjustments, demonstrating the system's response to transient shocks. The lag lengths p and q denote the optimal number of periods for the dependent and independent variables, respectively, with Δ signifying short-run changes and η indicating the rate at which deviations from equilibrium are rectified via the error correction mechanism. The ARDL approach is adopted due to several advantages. First, it is suitable for small sample sizes, which is relevant for this study given the limited time-series observations. Second, it allows for the simultaneous estimation of short-run and long-run relationships within a single framework (Abdi, Mohamed, Mohamed, et al., 2025; Mohamed, 2024; Mohamed et al., 2025; Mohamed & Abdi, 2024). Third, it can be applied when variables are integrated of mixed orders $I(0)$ and $I(1)$, provided that none is integrated of order $I(2)$.

To determine whether a long-run relationship exists between the variables, the study applies the bounds testing approach. Using the Wald F-statistic, the method tests the null hypothesis of no

cointegration against the alternative of a long-run association. A computed statistic above the upper critical bound $I(1)$ confirms the presence of cointegration, while a value below the lower bound $I(0)$ suggests its absence. If the statistic falls between these bounds, the result is considered inconclusive. By combining both long- and short-term dynamics, this approach provides a clear framework for understanding equilibrium relationships and the ways in which variables adjust over time, offering a detailed view of the temporal interactions that shape the system.

3. Results and discussion

The empirical results are reported using standard statistical criteria, including coefficient estimates, significance levels (1, 5, and 10%), and diagnostic test outcomes to ensure robustness and reliability. The analysis focuses on both the magnitude and statistical significance of the estimated coefficients to evaluate the short-run and long-run effects of the explanatory variables on food production.

3.1. Descriptive and correlation statistics

The summary statistics, as shown in Table 2, provide insights into the distributional characteristics of the variables under consideration. The mean value of the logarithm of the food production index is -1.99 , with a low standard deviation of 0.042 , indicating limited variability in food production levels across the study period. The logarithms of capture fisheries and industrialization have mean values of 4.46 and 1.58 , respectively, while institutional quality and income inequality average -2.21 and 2.66 . Among the variables, institutional quality displays the highest dispersion of 0.142 , suggesting that governance dynamics have undergone notable fluctuations over time. The Jarque-Bera statistics reveal that the null hypothesis of normality is rejected for Lnfp , Lncf , and Lniq , indicating that these variables are not normally distributed, potentially due to structural or policy shocks, while income inequality and industrialization are normally distributed. On the other hand, the correlation matrix in Table 2B reveals a negative association between food production and capture fisheries (-0.25), income inequality (-0.38), and industrial development (-0.59). Conversely, a positive correlation exists between institutional quality and food production (0.20).

3.2. Unit root and structural break tests

To assess the stationarity properties of the variables, the study employs the Dickey-Fuller Min- t unit root test, which is specifically suited to small sample sizes and provides robust estimates (Abdi, Mohamed, Mohamed, et al., 2025). Furthermore, recognizing the possibility of abrupt policy changes or conflict-induced disruptions in Somalia, the study applies structural break tests using both Additive Outlier (AO) and Innovative Outlier (IO) models. These models detect significant breakpoints, particularly for food production and institutional quality, reinforcing the notion that Somali macroeconomic time series are subject to instability caused by governance changes, climate shocks, or external aid inflows.

Table 2. Summary statistics.

(A) Descriptive summary							
	Mean	Maximum	Minimum	Std. Dev.	Jarque-Bera	Probability	Observations
Lnfp	-1.985812	-1.853698	-2.041985	0.041823	14.43739	0.000733	30
Lncf	4.462337	4.510545	4.376577	0.033161	10.62405	0.004932	30
Lngini	1.700208	1.738876	1.675595	0.02577	3.581071	0.166871	30
Lnind	7.821275	8.29493	7.346143	0.303117	1.842383	0.398044	30
Lniq	-0.000922	0.60206	-0.30103	0.142142	141.6624	0	30
(B) Correlation							
	Lnfp	Lncf	Lngini	Lnind	Lniq		
Lnfp	1	-0.412925819	-0.517687178	-0.649415499	0.428966394		
Lncf	-0.412925819	1	0.394626636	0.354887371	-0.542692077		
Lngini	-0.517687178	0.394626636	1	0.949806835	-0.487611587		
Lnind	-0.649415499	0.354887371	0.949806835	1	-0.532967439		
Lniq	0.428966394	-0.542692077	-0.487611587	-0.532967439	1		

Source: Author's computation.

Table 3. Dickey-Fuller Min-*t* unit root test.

Variable	Innovative outlier		Additive outlier	
	<i>t</i> -Statistics	Break data	<i>t</i> -Statistics	Break data
Lnfpj	-4.925**	2017	-3.792	1993
ΔLnfpj	-8.009***	1996	-8.052**	2014
Lncf	-7.060**	2006	-5.482**	2008
ΔLncf	-10.066**	1995	-5.428**	2008
Lnjini	-5.115***	2002	-5.223***	2003
ΔLnjini	-2.082	2016	-1.851	2012
Lnind	-5.696	2014	-4.374*	2007
ΔLnind	-5.970***	1996	-6.478***	1996
LnIQ	-10.623***	2018	-13.069***	2017
ΔLnIQ	-13.633***	2017	-8.352***	2017

Notes: Δ represents the first difference. The reported test statistics are based on an intercept-only model. ***, **, and * denote significance at the 1, 5, and 10% levels, respectively.

Source: Author's computation.

Table 4. Bounds testing using the Pesaran, Shin, and Smith approach.

Statistic	<i>k</i>	10%		5%		<i>p</i> -Value		
		I(0)	I(1)	I(0)	I(1)	I(1)	I(0)	
<i>F</i>	8.921	4	2.181	3.462	2.736	4.222	0.000	0.001
<i>t</i>	-3.954	4	-1.613	-3.247	-1.991	-3.689	0.001	0.032

Source: Author's computation based on ARDL bounds test results.

The results presented in Table 3 indicate a mixed order of integration among the series—*I*(0) and *I*(1)—with no variable being integrated of order two. Food production and institutional quality exhibit stationarity only after first differencing, while others are stationary at levels, justifying the adoption of the ARDL bounds testing approach for the Cointegration analysis (Mohamed, 2024; Mohamed et al., 2025; Mohamed & Abdi, 2024).

3.3. ARDL bounds cointegration analysis

To investigate the existence of a long-run relationship among the variables, the study applies the ARDL bounds testing approach developed by Pesaran et al. (2001). In Table 4, the calculated *F*-statistic of 8.921 surpasses the upper critical bounds at both the 5 and 10% significance levels, confirming the existence of a long-run Cointegration relationship among food production, capture fisheries, income inequality, industrial development, and institutional quality. The *t*-statistic associated with the lagged dependent variable is also statistically significant, offering additional evidence of long-run convergence among the variables. This implies that food production in Somalia is systematically and jointly influenced by these structural indicators over time.

3.4. Long-run and short-run dynamics

To understand the varying impacts of the key variables on food security, we examine both the long-run and short-run relationships between the capture fisheries, industrial development, institutional quality, and income inequality, alongside their influence on food production in Somalia. The results in Table 5 indicate that there is a favorable and statistically significant relationship between the capture fisheries and food security in Somalia. Specifically, a 1% increase in capture fisheries leads to a 0.092% increase in the food production index in the long run. In the same vein, Industrial development exhibits the largest long-run elasticity among the variables under study. A 1% increase in industrial development is associated with a 0.538% increase in food production. This strong positive relationship highlights the structural importance of industrial growth in fostering long-term improvements in food security.

Moreover, Institutional quality also shows a positive and statistically significant impact on food production in the long run. A 1% improvement in institutional quality leads to a 0.331% increase in food production. In contrast, the results reveal a negative and statistically significant long-run relationship

Table 5. Long run and short run result.

Variables	Coefficient
$Lniq_{t-1}$	0.229** (-0.104)
$Lncf_{t-1}$	0.711*** (-0.196)
$Lngini_{t-1}$	-1.477* (-0.782)
$Lnind_{t-1}$	0.175** (-0.0701)
$\Delta Lniq$	0.0940* (-0.0505)
$\Delta Lncf$	-0.00829 (-0.0856)
$\Delta Lngini$	-0.607 (-0.364)
$\Delta Lnind$	-0.239*** (-0.0832)
ECT_{t-1}	-0.411*** (-0.104)
Observations	28
R-squared	0.686

Notes: *Significant at the 10%; **Significant at the 5%;
***Significant at the 1%.

Source: Author's computation.

Table 6. Diagnostic tests.

Type	F/χ^2	p-Value	Decision
Breusch–Godfrey LM test	1.017	0.3252	No serial correlation
Heteroskedasticity	28	0.411	Homoscedasticity
Cameron and Trivedi's decomposition of the Jarque-Bera normality test.			
Skewness	5.55	0.5933	Residuals are normally distributed
Kurtosis	0.01	0.9343	Residuals are normally distributed

Source: Author's computation.

between income inequality and food production. A 1% increase in income inequality results in a 0.400% decline in the food production index. This inverse relationship underscores the extent to which disparities in income distribution can adversely affect long-term food production outcomes.

Turning to the short-run dynamics, the model shows that industrial development maintains a positive and statistically significant effect on food production. A 1% increase in industrial development leads to a 0.219% increase in food security in the short term. This result indicates that even in the absence of structural changes, short-term variations in industrial activity can generate immediate improvements in food output. Noteworthy, institutional quality also demonstrates a positive short-run effect. A 1% improvement in institutional quality results in a 0.180% increase in food production. This suggests that policy changes or governance improvements have prompt and measurable impacts on food production performance in the short term. In contrast, the capture fisheries does not exhibit a statistically significant short-run effect on food production. Although its long-run contribution is evident, the short-run coefficient lacks significance, indicating that maritime and coastal sector developments may take longer to influence food output due to infrastructural and policy lag effects. Likewise, income inequality does not yield a statistically significant short-run effect on food production. This result suggests that fluctuations in inequality have less immediate influence on food availability, though their adverse consequences become pronounced over the long run through reduced access to productive resources and weakened inclusive growth mechanisms. The error correction term is -0.411 and statistically significant at the 1% level. This implies that ~41.1% of any deviation from the long-run equilibrium is corrected within a single year, indicating a moderate speed of adjustment and reinforcing the presence of a stable long-run relationship among the variables.

3.5. Diagnostic tests

Diagnostic assessments in Table 6 confirm the statistical validity of the ARDL model. The Breusch-Godfrey LM test shows no evidence of serial correlation, and the heteroskedasticity test fails to reject the null

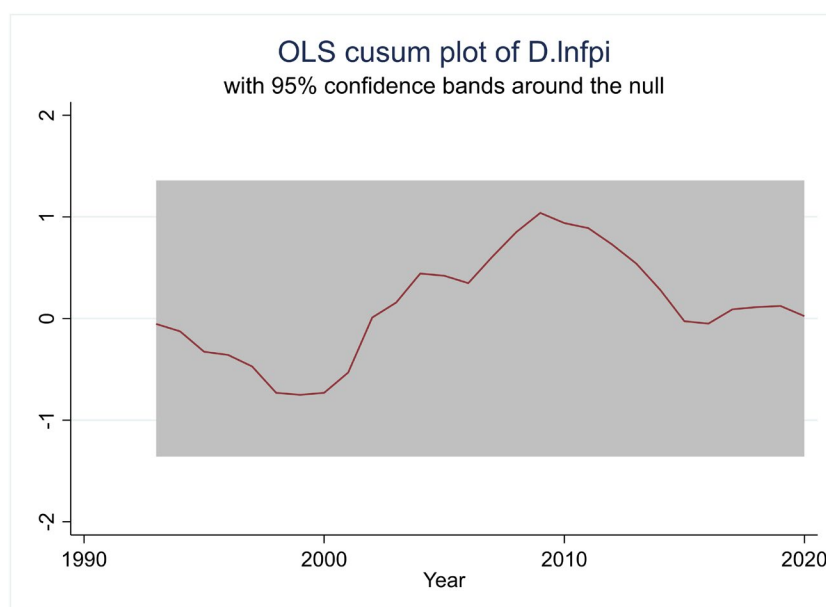


Figure 3. OLS CUSUM plot.

Table 7. Sensitivity analysis.

Variable	Coefficient	Std. error	t-Statistic	Prob.
LNCF	0.805968	0.091486	8.809713	0.072
LNGINI	-6.027707	0.346768	-17.38253	0.0366
LNIND	0.603324	0.031326	19.25969	0.033
LNIQ	1.391039	0.35555	3.912362	0.1593

Source: Author's computation.

hypothesis of constant variance. The normality test also supports the assumption that residuals are approximately normally distributed. These outcomes affirm the reliability of the estimates and the robustness of the empirical specification. Moreover, the OLS CUSUM plot for the differenced inflation variable reveals that the cumulative residuals stayed within the 95% confidence limits for the entire period from 1990 to 2020, confirming parameter stability, as illustrated in Figure 3.

3.6. Robustness analysis using DOLS

To validate the robustness of the ARDL findings, a Dynamic Ordinary Least Squares (DOLS) model is estimated. The DOLS results, reported in Table 7, are generally consistent with the ARDL estimates. capture fisheries activities and industrial development retain their positive and statistically significant coefficients, affirming their long-run contributions to food security. Although the coefficient of institutional quality remains positive, it loses statistical significance in the DOLS framework. Nevertheless, the convergence in coefficient signs and significance across both estimators enhances the credibility of the overall findings.

3.7. Causality analysis

To further explore the directional relationships among the variables, we examine the Granger causality results presented in Table 8. These results reveal that capture fisheries development Granger-causes food production, suggesting that maritime sector development is a predictive and policy-relevant driver of food security. This finding highlights the potential of the capture fisheries to influence food production by driving economic activities in coastal and maritime regions, which can enhance both resource availability and food distribution. Additionally, food production Granger-causes both income inequality and industrial development, indicating feedback effects whereby improvements in food systems contribute to

Table 8. Granger causality tests.

	<i>F</i> -statistic	Prob.
LNCF does not Granger cause LNFPI	5.40238	0.0282
LNFPI does not Granger cause LNCF	0.93818	0.3417
LNGINI does not Granger cause LNFPI	0.02574	0.8738
LNFPI does not Granger cause LNGINI	19.5857	0.0002
LNIND does not Granger cause LNFPI	0.25234	0.6197
LNFPI does not Granger cause LNIND	4.62668	0.0409
LNIQ does not Granger cause LNFPI	22.7615	6.00E-05
LNFPI does not Granger cause LNIQ	1.25754	0.2724

Source: Author's computation.

broader economic and social transformations. As food production rises, it can reduce income disparities by improving access to resources and stimulating industrial growth. Institutional quality also Granger-causes food production, affirming the directional influence of governance on agricultural productivity and distribution. This suggests that stronger institutions, through better policies and governance, can foster improvements in food production systems, thereby enhancing overall food security.

3.8. Discussion

The empirical findings from both the long-run and short-run models provide a nuanced understanding of the drivers of food security in Somalia, particularly through the lenses of the capture fisheries, industrial development, institutional quality, and income inequality. These results are largely in line with previous empirical studies, while also presenting some distinct contrasts that underscore the unique socio-political and economic dynamics of Somalia.

The positive and significant effect of capture fisheries development on food production is consistent with the findings of Bennett et al. (2019, 2023), who emphasize that sustainable ocean-based activities can significantly enhance food security, especially in coastal nations with rich marine ecosystems. Similarly, Pauly and Zeller (2016) argue that artisanal fisheries contribute meaningfully to both income generation and food availability in developing countries. These perspectives affirm the potential of Somalia's extensive coastline to support food security through fisheries, marine agriculture, and port-based trade. However, compared to more institutionalized maritime sectors in countries such as Mauritius and Seychelles, Somalia's maritime governance remains underdeveloped. As such, the policy challenge lies in transitioning from informal and fragmented fishing practices to a more structured and regulated fisheries sector that promotes sustainability, inclusion, and resilience to climate and security risks. From the perspective of Somalia's food production dynamics, the results highlight the importance of both traditional agricultural systems and complementary sectors such as capture fisheries and industrial development. The positive contribution of capture fisheries reflects the role of marine resources in supporting food availability, particularly in coastal regions, while industrial development enhances value addition and strengthens supply chains. These interactions suggest that food production in Somalia is not solely determined by agricultural inputs, but by a broader system shaped by sectoral linkages and institutional conditions. These findings further emphasize the importance of sectoral integration and institutional capacity in improving food production outcomes and supporting more efficient distribution within Somalia's food system.

The strong positive elasticity of industrial development corroborates the findings of Gollin et al. (2002), who highlight the critical role of structural transformation and agro-industrial linkages in increasing agricultural productivity and food output. Likewise, studies by Dorosh and Thurlow (2018) in sub-Saharan Africa reveal that rural industrialization and investment in agricultural processing infrastructure directly reduce food insecurity by enhancing value chains and reducing post-harvest losses. The Somali context, however, adds a layer of complexity, as industrial development is hampered by weak infrastructure, limited energy access, and fragile institutions. This calls for integrated industrial-agricultural development policies that can bridge the rural-urban divide and stimulate local economies through small- and medium-scale agro-industrial enterprises. These findings align with the study objectives by demonstrating how industrial development strengthens value chains and contributes to improved food production outcomes within Somalia's evolving food system.

Moreover, Institutional quality's positive long-run effect on food production is consistent with empirical evidence from Kaufmann et al. (2010), who argue that governance quality—including rule of law, regulatory efficiency, and anti-corruption measures—directly influences the effectiveness of agricultural policy. In fragile states, as underscored by Acemoglu and Robinson (2012), institutional weakness perpetuates poverty traps and hinders inclusive development. Our results confirm that Somalia's food system is highly sensitive to improvements in institutional functionality, suggesting that reforms in land governance, local administrative capacity, and public sector accountability could yield tangible gains in food availability and access. These findings underscore the importance of institutional capacity in developing sustainable food production and distribution systems in Somalia.

Conversely, the negative impact of income inequality on food production aligns with the findings of Galor and Zeira (1993), who emphasize that high inequality restricts human capital investment and productive capacity among disadvantaged groups. Studies by Jayne et al. (2010) in East Africa similarly show that unequal access to land, inputs, and credit exacerbates food insecurity, particularly in conflict-affected settings. Somalia's historical and clan-based inequalities are particularly entrenched, making redistributive interventions more challenging yet increasingly essential. These include equitable land tenure reforms, social protection systems, and gender-sensitive rural finance programs. However, some findings diverge from the global literature. For instance, in contrast to studies by Ravallion and Chen (2003), which show that inequality sometimes coexists with rising output during early growth phases, our study reveals that inequality in Somalia is immediately and consistently detrimental to food production. This could be due to the fragility of Somalia's political economy, where unequal power distribution leads not to efficient capital accumulation but to exclusion and marginalization of rural producers. These results align with the study objectives by emphasizing how inequality constrains productive capacity and undermines inclusive food production dynamics within Somalia's food system.

The short-run dynamics also provide insight into the temporal responsiveness of the food system. The positive short-run impacts of industrial development and institutional quality imply that policy interventions targeting these areas can generate relatively quick improvements in food production. This aligns with evidence from Diao and McMillan (2018), who found that industrial and institutional reforms in Ethiopia and Rwanda led to rapid agricultural responses. For Somalia, these findings suggest that targeted, short-term policy instruments—such as investment incentives for agro-processing or administrative decentralization of agricultural services—could help stabilize food systems even amid longer-term structural reforms.

Beyond structural determinants, the findings can also be interpreted through the lenses of vulnerability and resilience within Somalia's food system. In fragile contexts, food production is highly sensitive to external shocks such as droughts, conflicts, and global disruptions, including pandemic-related supply constraints. In this regard, strengthening institutional capacity and promoting sectoral integration not only enhances production outcomes but also improves the adaptive capacity of rural households and small-scale producers. These dynamics highlight the importance of empowerment-oriented policies—such as improved access to inputs, inclusive financing, and localized governance mechanisms—in building a more resilient and sustainable food production system in Somalia. In the post-2020 context, these findings are increasingly relevant, as disruptions such as COVID-19 and supply chain shocks have exposed the vulnerability of food systems in fragile economies. For Somalia, strengthening institutions, promoting agro-industrial development, and supporting fisheries are essential not only for improving food production but also for enhancing resilience to future shocks. These insights offer useful guidance for building more adaptive and inclusive food systems.

4. Conclusion and policy implication

Understanding the drivers of food production is essential for developing economies such as Somalia, where agricultural systems, fisheries, and value chain structures are shaped by structural vulnerabilities, climatic shocks, and institutional constraints. This study examines the key determinants of food production by integrating capture fisheries, income inequality, institutional quality, and industrialization within a dynamic econometric framework. Using ARDL bounds testing, causality analysis, and robustness

estimators, the analysis provides insight into how these factors interact within Somalia's broader food production system, encompassing primary production, processing, and distribution dynamics.

The findings reveal four key insights. Initially, the capture fisheries demonstrate a beneficial and statistically significant effect on food production, underscoring its unexploited potential as a fundamental element of national food security. The extensive coastline of Somalia, when effectively managed through sustainable fisheries practices and robust maritime governance, holds the potential to greatly enhance food availability, generate employment opportunities, and diversify export markets. Furthermore, industrialization reveals a considerable positive effect, indicating that structural transformation and agro-industrial linkages are crucial for improving productivity, value addition, and technological advancement in the food sector. Thirdly, the quality of institutions emerges as a crucial element affecting productive efficiency and sustainability. Robust governance structures, clear policies, and efficient regulatory frameworks enhance agricultural investment, resource distribution, and sustainable resilience over time. On the other hand, income inequality has a detrimental effect, indicating that imbalances in income distribution impede access to resources, diminish domestic demand, and undermine incentives for rural production, ultimately limiting the effectiveness of food systems. Together, these findings highlight that Somalia's food production system is shaped by the interaction between farming activities, fisheries, and structural-economic conditions, rather than isolated sectoral performance.

The findings highlight the importance of adjusting Somalia's development strategy to focus on a cohesive and resilient food system. Firstly, advancing a transformation driven by the Fisheries sector is essential. This involves establishing a structured approach to the fisheries sector, enhancing coastal infrastructure, promoting private-sector involvement, and implementing sustainable harvesting practices to ensure the long-term productivity of marine resources. Secondly, promoting industrial diversification—especially via agro-industrial development—ought to be a national priority. Creating agro-processing zones, investing in technological advancements, and reinforcing rural-urban value chains will improve production efficiency, minimize post-harvest losses, and promote job creation. Thirdly, institutional reforms should be a key focus of the country's food production agenda. Improving governance quality by implementing anti-corruption mechanisms, increasing data transparency, and fostering effective coordination among agricultural, environmental, and industrial organizations will lead to coherent policy execution. Institutional modernization must incorporate food security metrics into national development plans and fiscal frameworks to ensure that sectoral strategies are aligned with long-term sustainability objectives.

Fourthly, tackling income inequality necessitates the implementation of inclusive policy instruments—such as equitable land reforms, rural credit schemes, and targeted social protection programs—that empower marginalized producers and enhance access to productive assets. In addition to targeted reforms within specific sectors, Somalia is in critical need of a National Food Security and Blue Growth Strategy. This strategy should serve as a comprehensive framework that integrates marine resources, industrial development, and institutional transformation, all aligned under a cohesive vision. A policy of this nature should utilize regional collaborations, climate finance strategies, and digital advancements to improve resilience and sustainability throughout the food system. These findings have broader implications for food production systems in Somalia and similar fragile economies in Africa, where integrated approaches that link farming systems, fisheries, and value chains are essential for achieving sustainable food security. The results suggest that policies should move beyond sector-specific interventions toward coordinated strategies that address production, distribution, and institutional constraints simultaneously.

This study acknowledges certain limitations despite its contributions. The analysis primarily emphasizes macroeconomic and institutional determinants, while overlooking potentially significant factors such as climatic variability, conflict dynamics, and remittance flows that also impact agricultural productivity. Furthermore, the dependence on aggregate time-series data may mask regional variations across Somalia's diverse agro-ecological zones. Future research should incorporate spatially disaggregated datasets, utilize nonlinear and machine-learning models, and examine cross-sectoral linkages between agriculture, fisheries, and climate resilience. These extensions would enhance the analytical comprehension of food production systems and offer a more robust empirical basis for evidence-driven policymaking.

Ethical approval

This research adhered to the ethical standards of the writing process. This text is original, has not been previously published, and is not under consideration for publication anywhere.

Consent to participate

Not applicable.

Consent for publication

Not applicable.

Author contributions

CRedit: **Abdisalan Aden Mohamed**: Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Project administration, Resources, Software, Writing – original draft, Writing – review & editing; **Zakarie Abdi Warsame**: Conceptualization, Project administration, Resources, Validation, Visualization, Writing – original draft; **Abdirahman Mustaf Abdullahi**: Methodology, Project administration, Supervision, Validation; **Abdifatah Mohamed Muhumed**: Conceptualization, Supervision, Validation, Writing – review & editing.

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Data availability statement

The datasets used and/or analyzed during the current study are available from the corresponding author, Abdisalan Aden Mohamed, upon reasonable request (email: abdisalanaden09@gmail.com).

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