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Mohamed Muhumed Hassan

Mohamedmuhumedxasan@gmail.com

Somali National University

Ali Yuusuf Mohamud

Somali National University

Aisha Abdilkadir Diriye

Somali National University

Najma Mukhtar Hassan

Somali National University

Isack Abdi Bilow

Somali National University

Research Article

Keywords: Life expectancy, Gross national income, Official development assistance, Water stress, Immunization, Somalia, ARDL model

Posted Date: November 24th, 2026

DOI: https://doi.org/10.21203/rs.3.rs-11480723/v1

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Additional Declarations: No competing interests reported.

National Prosperity and Hydrological Security as Determinants of Life Expectancy in Somalia

Corresponding author: Mohamed Muhumed Hassan (https://orcid.org/0009-0003-8970-2825) , Department of Statistics and Planning, Somali National University, Mogadishu, Somalia. Email:Mohamedmuhumedxasan@gmail.com

Ali Yuusuf Mohamud, Department of Statistics and Planning, Somali National University, Mogadishu, Somalia. Email: calijilib31@gmail.com

Aisha Abdilkadir Diriye, Department of Statistics and Planning, Somali National University, Mogadishu, Somalia. Email: ishaaupdykadir@gmail.com

Najma Mukhtar Hassan, Department of Statistics and Planning, Somali National University, Mogadishu, Somalia. Email: Najmamuqtar595@gmail.com

Isack Abdi Bilow, (https://orcid.org/0009-0005-3063-4340), Department of Statistics and Planning, Somali National University, Mogadishu, Somalia. Email: bilow@snu.edu

ABSTRACT

This study examines the effects of national prosperity, official development assistance, water stress, and immunization on life expectancy in Somalia using annual time-series data from 1987–2022. The Autoregressive Distributed Lag (ARDL) model was employed to estimate short-run and long-run relationships, while FMOLS, DOLS, and CCR estimators were used to assess the robustness of the long-run results. The findings reveal a stable long-run relationship among the study variables. Gross national income (GNI) has a positive and statistically significant effect on life expectancy, whereas official development assistance (ODA) and water stress exert negative and statistically significant effects in the long run. Immunization demonstrates a positive and statistically significant long-run effect in the ARDL model, although its coefficient is statistically insignificant across the robustness estimators. The results also indicate that water stress has a negative long-run association with life expectancy, with its statistical significance varying across the alternative estimators. Based on these findings, the study recommends

promoting sustainable economic growth, strengthening water-resource management and climate-resilient infrastructure, expanding immunization coverage, and improving the coordination and effectiveness of development assistance to enhance population longevity and sustainable human development in Somalia.

Keywords: Life expectancy; Gross national income; Official development assistance; Water stress; Immunization; Somalia; ARDL model.

1. Introduction

Life expectancy at birth is the number of years a newborn would be expected to live if the mortality patterns prevailing at the time of its birth remained constant throughout life (World Bank, 2026). Because it aggregates mortality risk across every age group, it is one of the most widely used indicators of population health and of national development (Cutler et al., 2006; Deaton, 2003). Its determinants are socioeconomic, health-system, demographic and environmental rather than any single factor in isolation. Mondal and Shitan (2014) identified Gross National Income (GNI) per capita as a key determinant across 91 low- and lower-middle-income countries, alongside fertility and physician density. Hauck et al. (2016) found that clean water, sanitation and overseas development assistance were among the social determinants most robustly associated with longevity in 54 low-income countries, and Salami et al. (2019) showed that improved water access and urbanization drove life-expectancy gains across 52 African countries, with an impact that grew over time.

Global life expectancy rose from 66.8 years in 2000 to 73.1 years in 2019 before COVID-19 disrupted progress (WHO, 2024). The gains have been uneven: life expectancy at birth has converged across 201 countries, yet large disparities persist, with the weakest performers concentrated in Southern and Western Africa and Oceania (Liou et al., 2020), while life expectancy at age 65 has diverged since 1960 (Aksan & Chakraborty, 2023). Sub-Saharan Africa has improved considerably, but regional life expectancy was still about 63 years in 2024 (World Bank, 2024), and income growth, urbanization and clean-water access are positively associated with longevity there (Chewe & Hangoma, 2020). Somalia remains below this benchmark at about 59 years (World Bank, 2024). Its population health is shaped by prolonged conflict, recurrent drought and flood, disease outbreaks, displacement and a chronically weakened health system (Morrison & Malik, 2023; WHO, 2025).

National income is a natural starting point for explaining this gap. Dhungana et al. (2024) found a significant long-run relationship between GNI per capita and life expectancy in eight South Asian countries, and Kontodimopoulos (2022) showed across 172 countries that income matters alongside, rather than instead of, poverty, education, inequality and healthcare resources. Somali evidence relies on GDP per capita: Dahir et al. (2026) found a significant positive long-run effect of economic development on life expectancy, and Mohamed et al. (2025) documented a close long-run comovement between GDP per capita and life expectancy. Whether the relationship holds for

GNI, which includes income earned abroad, is untested. This matters for an economy whose resident income depends on external flows.

External assistance is a second candidate. Official Development Assistance (ODA) comprises grants and concessional flows from bilateral and multilateral sources (Stojanov et al., 2019) and is especially important in fragile contexts (Desai, 2020). Its relationship with longevity is contested: broad ODA has a negative and significant association with life expectancy across developing countries (Nwude et al., 2020), health-specific aid is associated with higher life expectancy and lower under-five mortality (Bendavid & Bhattacharya, 2014), and humanitarian aid in Somalia is negatively associated with life expectancy (Dahir et al., 2026). The wider aid-effectiveness debate is similarly unsettled (Burnside & Dollar, 2000; Rajan & Subramanian, 2008; Clemens et al., 2012).

Preventive health services are a third. Vaccination is estimated to have averted 154 million deaths since 1974 and to account for 52 percent of the infant-mortality decline in Africa (Shattock et al., 2024). Yet in Somalia, 2025 coverage was only 72 percent for DTP3 and 61 percent for MCV1 (WHO & UNICEF, 2026). Rural nomadic children are significantly more likely to be zero-dose (Mohamoud et al., 2024), and nomadic groups, displaced persons and residents of remote or Al-Shabaab-controlled areas are least reached (Bile et al., 2024), constrained by shortages of drugs, diagnostics and trained staff (Abdi et al., 2025).

Environmental pressure is a fourth. Water stress, the ratio of freshwater withdrawals to available renewable freshwater after environmental requirements (FAO & UN-Water, 2024), had a significant negative long-run association with life expectancy in seven emerging economies, net of health expenditure and urbanization (Ge & Wu, 2025). The human cost of hydrological shocks in Somalia is direct: about 44,700 excess deaths are estimated for the 2017-2018 drought-related crisis alone (Warsame et al., 2023). Despite this evidence, no Somali study jointly incorporates national income, total ODA, immunization and water stress. The closest study, Dahir et al. (2026), used GDP per capita and humanitarian ODA and omitted water stress.

This study addresses that gap by estimating the short-run and long-run relationships between life expectancy and GNI, ODA, immunization and water stress in Somalia over 1987-2022, using an Autoregressive Distributed Lag (ARDL) bounds-testing framework (Pesaran et al., 2001). It tests four hypotheses: GNI and immunization are positively related to life expectancy,

water stress is negatively related, and ODA has a relationship of unspecified sign, given the contested evidence above. The study contributes in three ways. It adds hydrological pressure to the Somali life-expectancy literature, it replaces GDP per capita and humanitarian aid with GNI and total ODA, and it separates short-run adjustment from long-run equilibrium in a shock-prone economy. Its findings are intended to inform policymakers and development partners in health, economic planning, water-resource management and aid coordination, and to serve as a base for future work with additional determinants such as political instability, health expenditure and nutrition.

2. Literature review

The relationship between income and population health has been central to development economics since Preston (1975) documented a concave but robust association between national income and life expectancy. Pritchett and Summers (1996) argued that the relationship is causal, running from income to health, and Deaton (2003) and Cutler et al. (2006) later qualified this by stressing the roles of public health, knowledge and institutions. The theoretical anchor is Grossman's (1972) health capital model, in which health is a durable stock that depreciates with age and is replenished by investment financed from income. At the national level, higher GNI should expand capacity to invest in medical care, nutrition and sanitation (Kaluarachchi & Jayathilaka, 2026; Kontodimopoulos, 2022). The model, however, implicitly assumes that health-producing inputs are physically available. In a water-stressed, drought-prone country this assumption fails, and environmental health economics treats safe water as a necessary and only partly substitutable input (Majeed & Luni, 2026; Ge & Wu, 2025). Where freshwater is under sustained stress, the health yield of a given income falls, because no feasible spending can fully offset absolute scarcity of safe water (Fuente et al., 2020). This study therefore extends the Grossman framework: life expectancy in Somalia is jointly determined by financing capacity (GNI) and hydrological adequacy (water stress), with ODA and immunization acting as complementary inputs into the same health-production process.

Empirical evidence on national income is broadly positive. Mondal and Shitan (2014) identified GNI per capita as a key determinant of life expectancy in low- and lower-middle-income countries, and Kontodimopoulos (2022) found that the strength of the income-health relationship differs by level of development. Dhungana et al. (2024) used a vector error-correction framework comparable to ARDL and found a significant long-run GNI-life expectancy relationship in South

Asia. Kaluarachchi and Jayathilaka (2026) found that income remained a robust predictor across World Bank income groups, with diminishing marginal effects at higher incomes. In Sub-Saharan Africa, per-capita income growth is positively associated with life expectancy (Chewe & Hangoma, 2020), and the global convergence documented by Liou et al. (2020) and Aksan and Chakraborty (2023) is consistent with the diminishing-returns logic of Grossman (1972). For Somalia, Dahir et al. (2026) and Mohamed et al. (2025) both reported positive long-run links between GDP per capita and life expectancy.

Evidence on aid is considerably more contested, reflecting a wider debate on aid effectiveness (Burnside & Dollar, 2000; Rajan & Subramanian, 2008). Nwude et al. (2020) found that broad ODA reduced life expectancy across developing countries, which they attribute partly to weak absorptive capacity and governance constraints. In contrast, Bendavid and Bhattacharya (2014) found that health-specific aid raised life expectancy and reduced under-five mortality, with benefits lasting several years. This contrast suggests that the sectoral composition of aid matters as much as its volume. Clemens et al. (2012) add that the timing of measurement affects estimated aid effects. For Somalia, Dahir et al. (2026) found a significant negative long-run association between humanitarian ODA and life expectancy, consistent with aid-dependency concerns raised by Mohamed et al. (2025). Because humanitarian flows rise sharply during crises that themselves depress life expectancy, this association may reflect the timing of disbursement rather than harm caused by aid. Whether total ODA behaves differently remains unanswered.

The immunization literature is the most consistently positive. Shattock et al. (2024) estimated that vaccination accounts for about 40 percent of the global decline in infant mortality and 52 percent in Africa, making it the largest single contributor to infant survival over five decades. Nwude et al. (2020) found that childhood measles immunization is positively associated with life expectancy across developing countries, and Dahir et al. (2026) reported a similar but only marginally significant association in Somalia. The Somali literature, however, reveals heterogeneity beneath this relationship. Mohamoud et al. (2024) found that rural nomadic children are significantly more likely to be zero-dose, Bile et al. (2024) identified nomadic, displaced and conflict-affected populations as least reached owing to weak delivery infrastructure and limited community engagement, and Abdi et al. (2025) documented shortages of essential drugs, diagnostic capacity and trained personnel. The direction of the effect is therefore clear, but its realized magnitude in Somalia may be dampened.

The water-health literature is smaller but consistently negative. Ge and Wu (2025) used a cross-sectionally augmented ARDL estimator and found a significant negative long-run effect of water stress on life expectancy in seven emerging economies. Majeed and Luni (2026) found that declining water quality reduces health outcomes more severely in less developed countries, and Fuente et al. (2020) forecast that economic growth alone will not eliminate water- and sanitation-related mortality in many Sub-Saharan countries by 2050, supporting the view that income and water security operate through partly independent channels. Complementary African evidence shows that clean-water access, rather than health expenditure alone, drove life-expectancy gains (Salami et al., 2019), and that improved environmental quality raised long-run life expectancy across 24 African countries (Beyene & Kotosz, 2021). In Somalia, Warsame et al. (2023) estimated about 44,700 excess deaths during the 2017-2018 drought-related crisis.

In summary, national income, immunization and water security are consistently related to life expectancy in the literature, while the effect of aid depends on its type and context. Despite this depth, no identified study jointly models GNI and water stress as parallel determinants of Somali life expectancy within a single ARDL equation that also controls for total ODA and immunization. Dahir et al. (2026) used GDP per capita and humanitarian ODA and omitted water stress, and the continental water-stress evidence (Ge & Wu, 2025; Beyene & Kotosz, 2021; Salami et al., 2019) has not been tested in a Somali time-series framework. By estimating short-run and long-run relationships in a unified error-correction model (Pesaran et al., 2001), this study closes both gaps and provides country-specific evidence on how prosperity and hydrological security jointly relate to life expectancy in Somalia.

3. Data and Methods

3.1 Data

This study uses annual time-series data from 1987 to 2022 to examine how national prosperity, development assistance, hydrological security, and immunization influence population longevity in Somalia. The specification of the Autoregressive Distributed Lag (ARDL) model was employed to investigate both the short-run and long-run relationships among the study variables. The study period is determined by the availability of consistent data for all variables covering 1987–2022. The study consists of five variables: the dependent variable is Life Expectancy (LE), which represents population longevity, while the independent variables are Gross National Income (GNI), Official Development Assistance (ODA), Water Stress (WST), and Immunization (IMM).

The data was obtained from internationally recognized sources, as indicated in Table 1. The study uses EViews 12, a comprehensive econometric software package, for data analysis and econometric modeling.

Table 1: Variable descriptions and sources.

Variables	Description	Code	Source
Life Expectancy	Life expectancy at birth, total (years)	LE	World Bank (WDI)
GNI	Gross national income (GNI), measured in current US dollars and transformed into natural logarithm	GNI	FRED
ODA	Net official development assistance and official aid received, measured in constant US dollars and transformed into natural logarithm	ODA	World Bank (WDI)
Water Stress	Annual level of water stress, representing freshwater withdrawal as a proportion of available freshwater resources	WST	World Bank (WDI)
Immunization	Immunization rate, measured as the percentage of the relevant population receiving recommended vaccination coverage	IMM	World Bank (WDI)

3.2 Estimation Strategies:

This study implements the Autoregressive Distributed Lag (ARDL) approach to analyze the relationship between Life Expectancy (LE) and key determinants, including Gross National Income (GNI), Official Development Assistance (ODA), Water Stress (WST), and Immunization (IMM) in Somalia. First, we conduct unit root tests Augmented Dicky-Fuller (ADF) and Phillips-Perron (PP) to establish the stationarity of the variables. The ARDL limits test was used to investigate cointegration among the variables, considering the individualities of the time-series data.

3.3 ARDL Model Estimation:

The ARDL model used in this study analyzes the long-run cointegration relationship between Life Expectancy, Gross National Income, Official Development Assistance, Water Stress, and Immunization in Somalia. Following the ARDL bounds testing approach developed by (Pesaran

et al., 2001), the analysis examines the relationship between population longevity and its key economic, developmental, hydrological, and health-related determinants. Equation (1) presents the mathematical form of the ARDL model, while the specific logarithmic and econometric forms used for the empirical estimation are presented in Equation (2)

Mathematical function.

$$LE = F(GNI, ODA, WST, IMM) \quad (1)$$

To improve the statistical properties of the data, reduce potential heteroscedasticity, stabilize the variance, and facilitate the interpretation of estimated coefficients, the relevant continuous variables were transformed into their natural logarithmic form before estimation. Accordingly, Gross National Income (GNI) and Official Development Assistance (ODA) are expressed in natural logarithmic form as lnGNI and lnODA, respectively. Life Expectancy (LE), Water Stress (WST), and Immunization (IMM) were retained in their original forms because their measurements are expressed in years or percentages and are directly interpretable in their respective units. These transformations are applied consistently throughout the ARDL estimation.

$$LE = \propto + lnGNI + lnODA + WST + IMM + \varepsilon \quad (2)$$

To capture the dynamics of long-run equilibrium relationships, this study adopts an Autoregressive Distributed Lag (ARDL) modelling framework. the general ARDL specification is presented in Equation (3), while the empirical ARDL model estimated for Somalia is specified in Equation (4) as follows:

$$Y_t = \propto_0 + \sum_{j-1}^{p} \gamma_j Y_{t-j} + \sum_{i-0}^{q} \emptyset_i X_{t-i} + \varepsilon_t \quad (3)$$

$$+ \sum_{i=1}^{p} \Delta\emptyset_1 LE_{t-i} + \sum_{j=1}^{s} \Delta\emptyset_2 lnGNI_{t-j} + \sum_{k=1}^{r} \Delta\emptyset_3 lnODA_{t-k} + \sum_{b=1}^{d} \Delta\emptyset_4 WST_{t-b}$$

$$+ \sum_{y=1}^{q} \Delta\emptyset_5 IMM_{t-y} + \epsilon_t \quad (4)$$

where p, s, r, d, and q are optimal lag lengths.

(Pesaran et al., 2001) proposed that F-statistics can be tested against critical values that jointly represent upper and lower boundaries. Where F-statistics exceed the upper critical value, it leads to the rejection of the null hypothesis, denoting the existence of a constant relationship. where the F-statistics are below the lower critical value, the null hypothesis (H0) is confirmed, although its relevance is not evident at the defined ranges.

3.4 ARDL short and long run imitation

This research uses the ARDL method to address all aspects of variable interaction, including both short-term and long-term aspects. The long-term coefficient estimate is defined by Equation (5), which not only produces values but also tests the parameters for integration. The ARDL equation attempts to include the ECT into its equation to produce short-term dynamic parameters using an estimate obtained from long-term values with an error correction term or ECT approach.

$$LE_t = \alpha + \beta_1 LE_{t-1} + \beta_2 lnGNI_{t-1} + \beta_3 lnODA_{t-1} + \beta_4 WST_{t-1} + \beta_5 IMM_{t-1} + \sum_{i=1}^{p} \Delta\emptyset_1 LE_{t-i} + \sum_{j=1}^{s} \Delta\emptyset_2 lnGNI_{t-j} + \sum_{k=1}^{r} \Delta\emptyset_3 lnODA_{t-k} + \sum_{b=1}^{d} \Delta\emptyset_4 WST_{t-b} + \sum_{y=1}^{q} \Delta\emptyset_5 IMM_{t-y} + \partial ECT_{t-1} + \epsilon_t \qquad (5)$$

where ∂ represents the coefficient of the ECT

4. Presentation and Analysis of Results

4.1. Descriptive Statistics

Descriptive statistics play a significant role in determining the main features and patterns of variables. Table 2 contains basic information about all the variables in the study, and it demonstrates that the number of observations for each variable is 36, their average values, and their minimum and maximum levels. This helped improve our comprehension of the data before conducting additional analyses. From the findings, Life Expectancy has an average of 49.468 and varies from 25.034 to 57.249. The lnGNI demonstrates variation, with an average of 21.836, varying from 20.350 to 23.042. In contrast, the lnODA has an average of 20.287, ranging from 18.638 to 21.928. The Water Stress levels have an average of 20.916, ranging from 6.024 to 24.527. Immunization has an average of 36.638, varying from 18 to 71.

Table 2: Descriptive statistics

Variable	No. of Observations	Mean	Median	Maximum	Minimum	Standard Deviation
LE	36	49.468	50.751	57.249	25.034	7.304
lnGNI	36	21.836	21.802	23.042	20.350	0.781
lnODA	36	20.287	20.521	21.928	18.638	0.923
WST	36	20.916	24.527	24.527	6.024	5.842
IMM	36	36.638	35.5	71	18	13.611

4.2. Correlation Analysis

The relationship between Life Expectancy and its principal determinants, as shown by the correlation analysis in Table 3, indicates that the variables are correlated to varying degrees. For instance, the positive relationship between Life Expectancy and lnGNI, with a correlation coefficient of 0.669553, indicates that higher levels of national income are associated with higher levels of life expectancy. Similarly, Life Expectancy has positive relationships with lnODA, Water Stress, and Immunization, with correlation coefficients of 0.159911, 0.488652, and 0.492872, respectively. This indicates that increases in these variables are associated with increases in Life Expectancy. The correlation between lnGNI and Water Stress is relatively strong and positive at 0.828513, while the relationship between lnGNI and Immunization is also strong and positive at 0.850869. Furthermore, lnODA and Immunization show a positive correlation of 0.548230, while Water Stress and Immunization are positively correlated at 0.674720. Overall, the correlation analysis indicates positive relationships among all the variables included in the study, with varying degrees of association.

Table 3: Correlation Analysis

Variable	LE	lnGNI	lnODA	WST	IMM
LE	1				
lnGNI	0.669553	1			
lnODA	0.159911	0.380552	1		
WST	0.488652	0.828513	0.002065	1	
IMM	0.492872	0.850869	0.548230	0.674720	1

4.3. Unit root results

The first stage of time-series analysis is to establish the order of integration of the variables. The ARDL model is appropriate when the variables are stationary at level I(0), first difference I(1), or a combination of both, but it is not applicable when any variable is integrated at the second difference I(2). Therefore, the Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) tests are employed to determine the stationarity properties of the variables and ensure that none of the variables is integrated of order two. The unit root test results presented in Table 4 show that Life Expectancy (LE) and Water Stress (WST) are stationary at level, indicating that they are integrated of order zero, I(0). In contrast, lnGNI, lnODA, and Immunization (IMM) are non-stationary at level but become stationary after first differencing, indicating that they are integrated of order one, I(1). The results from both the ADF and PP tests confirm that none of the variables is integrated of order two or higher. Therefore, there is no I(2) variable in the model, confirming that the ARDL bounds testing approach is appropriate for examining the long-run and short-run relationships between Life Expectancy and its determinants in Somalia.

Table 4: Unit root tests

Variables	ADF		PP		Decision
	Level	1st difference	Level	1st difference	
LE	-3.289**	-6.515***	-3.108**	-6.904***	I(0)
lnGNI	-0.999	-4.373***	-0.755	-4.409***	I(1)
WST	-2.908**	-1.294	-5.199***	-1.262	I(0)
lnODA	−1.254	−4.404*	0.896	-5.642***	I(1)
IMM	0.903	-4.711***	0.999	-8.733***	I(1)

Note: ***, **, and * represent significance at the 1%, 5%, and 10% levels, respectively.

4.4. F-Bound cointegration tests

Next, we examine whether a long-run cointegrating relationship exists among the variables in the model. To determine this, the calculated F-statistics are compared with the lower-bound I(0) and upper-bound I(1) critical values at the 1%, 5%, and 10% significance levels. As shown by the F-bound cointegration results in Table 5, the computed F-statistic of 4.641192 is higher than the upper-bound I(1) critical values at the 1%, 5%, and 10% significance levels, which are 4.37, 3.49,

and 3.09, respectively. Since the F-statistics exceed the I(1) bounds at all significance levels, the findings provide strong evidence of a long-run cointegrating relationship between Life Expectancy and the explanatory variables. This confirms the presence of a stable long-run equilibrium relationship among the variables, making the ARDL approach appropriate for analyzing both the long-run and short-run dynamics of the model.

Table 5: F-Bound cointegration tests

Test	**Value**	**K**	**Significance**	**Bounds test critical value**	
				I(0)	I(1)
			1%	3.29	4.37
F-statistic	4.641192	4	5%	2.56	3.49
			10%	2.2	3.09

Note: The critical values follow Narayan (2005), and K refers to the number of independent variables.

4.5. Long-run and Short-run elasticities

The next step of the analysis examines the effects of the selected variables on Life Expectancy in both the short run and the long run. Table 6 presents the estimated long-run and short-run effects of Gross National Income, Official Development Assistance, Water Stress, and Immunization on Life Expectancy in Somalia. The long-run results show that lnGNI has a positive and statistically significant effect on Life Expectancy, with a coefficient of 9.383211. This indicates that an increase in national income is associated with an improvement in population longevity. In contrast, lnODA has a negative and statistically significant coefficient of -5.099581, suggesting that higher official development assistance is associated with a decline in Life Expectancy in the long run. Water Stress also has a negative and statistically significant effect on Life Expectancy, with a coefficient of -1.420249, indicating that increasing pressure on available water resources is associated with lower population longevity. On the other hand, Immunization has a positive and statistically significant effect on Life Expectancy, with a coefficient of 0.245753, suggesting that improvements in immunization coverage contribute positively to population longevity.

The short-run results indicate that the lagged values of Life Expectancy are positive and statistically significant. Specifically, Δ(LE(-1)), Δ(LE(-2)), Δ(LE(-3)), and Δ(LE(-4)) have

coefficients of 1.015810, 0.552943, 0.380469, and 0.221040, respectively, indicating persistence in the short-run dynamics of Life Expectancy. Changes in lnGNI also have significant short-run effects, with the contemporaneous change having a positive coefficient of 6.082377, while its first lag has a negative coefficient of -5.778327. Similarly, changes in lnODA have significant effects, with Δ(lnODA) having a negative coefficient of -9.485067 and its first lag having a positive coefficient of 7.767130. Water Stress has a statistically significant negative short-run effect, with a coefficient of -6.372787. In contrast, the short-run effect of Immunization is positive but statistically insignificant, with a coefficient of 0.041656. Furthermore, the error correction term (ECM(-1)) is negative and highly statistically significant, with a coefficient of -1.992237. This indicates the presence of a long-run equilibrium relationship among the variables and suggests that deviations from the long-run equilibrium are corrected over time. Overall, the findings demonstrate that national income, development assistance, water stress, and immunization have important effects on Life Expectancy in Somalia, although the magnitude and direction of their effects differ between the short run and the long run.

Table 6: Long run and short run elasticities

Long run elasticities		**Short run elasticities**	
Variables	**Coefficient**	**Variables**	**Coefficient**
lnGNI	9.383211***	Δ(LE(-1))	1.01581***
lnODA	-5.099581***	Δ(LE(-2))	0.552943**
WST	-1.420249**	Δ(LE(-3))	0.380469***
IMM	0.245753**	Δ(LE(-4))	0.22104**
C	-28.86999	Δ (lnGNI)	6.082377**
		Δ (lnGNI(-1))	-5.778327*
		Δ (lnODA)	-9.485067***
		Δ (lnODA(-1))	7.76713***
		Δ (WST)	-6.372787***
		Δ (IMM)	0.041656
		ECM (-1)	-1.992237***

Note: ***, **, and * represent significance at the 1%, 5%, and 10% levels, respectively.

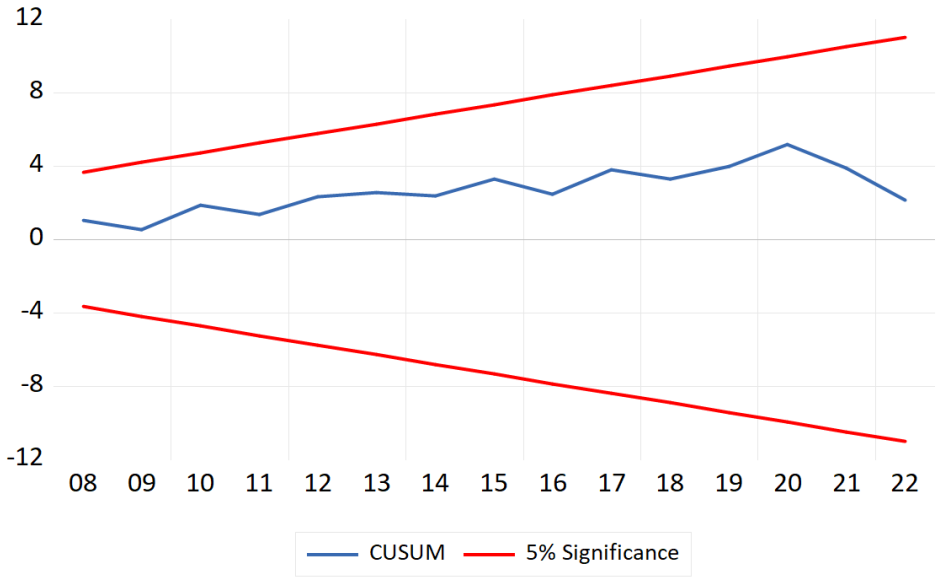
4.6. Diagnostic tests.

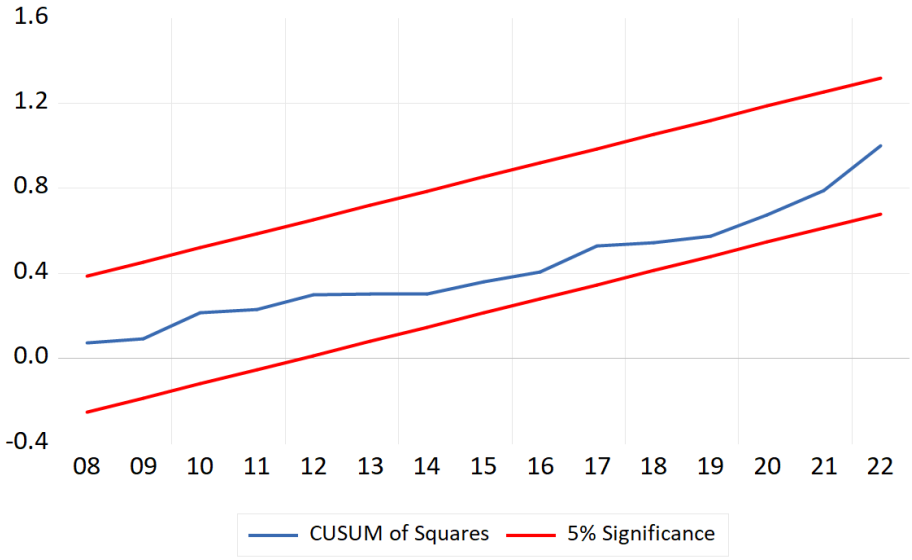
Various diagnostic tests were conducted to ensure the reliability and validity of the results obtained from the ARDL model. As shown in Table 7, the normality test reports a statistic of 0.342787 with a probability value of 0.842490. This indicates that the residuals are normally distributed. The Lagrange Multiplier (LM) test for serial correlation produces a statistic of 0.410143 with a probability value of 0.6718, indicating the absence of serial correlation in the model. In addition, the heteroscedasticity test reports a statistic of 0.605420 with a probability value of 0.8292, suggesting that the residuals have constant variance and that there is no evidence of heteroscedasticity. Furthermore, the model explains a substantial proportion of the variation in Life Expectancy, as indicated by an R-squared value of 0.882042 and an adjusted R-squared value of 0.823063. These results indicate a relatively strong explanatory power of the estimated model. In addition, the structural stability of the estimated ARDL model was examined using the cumulative sum (CUSUM) and cumulative sum of squares (CUSUMSQ) tests, as presented in Figures 1 and 2, respectively. These tests are used to assess whether the estimated coefficients remain stable over the study period.

Table 7: Diagnostic tests.

Normality Test	0.342787 (0.842490)
LM Test	0.410143 (0.6718)
Heteroscedasticity Test	0.605420 (0.8292)
R^2	0.882042
Adjusted R^2	(0.823063)

Note: Values in parentheses () represent probability.





4.7. FMOLS, DOLS, and CCR Estimators

Following the ARDL estimation, the robustness of the long-run relationship was assessed using the Fully Modified Ordinary Least Squares (FMOLS), Dynamic Ordinary Least Squares (DOLS), and Canonical Cointegrating Regression (CCR) estimators. As reported in Table 8, lnGNI exhibits a positive and statistically significant coefficient across all three estimators. In contrast, lnODA has a negative and statistically significant coefficient under FMOLS, DOLS, and CCR. Water stress (WST) consistently exhibits a negative coefficient across all estimators, although statistical significance is observed under DOLS and CCR but not FMOLS. Similarly, immunization (IMM) has a positive coefficient under FMOLS and CCR but a negative coefficient under DOLS;

however, its effect is statistically insignificant across all three estimators. Overall, the consistent signs and statistical significance of lnGNI and lnODA across the three estimation techniques support the robustness of their estimated relationships, while the varying significance of WST and the inconsistent signs of IMM indicate that these results are more sensitive to the estimation method.

Table 8 Results of FMOLS, DOLS, and CCR Estimators

Variable	**FMOLS Coefficient**	**FMOLS Std. Error**	**DOLS Coefficient**	**DOLS Std. Error**	**CCR Coefficient**	**CCR Std. Error**
lnGNI	9.832586***	2.543629	16.411850***	3.834443	10.330400***	2.385815
lnODA	-3.094001**	1.266761	-3.966376**	1.612183	-3.809064**	1.543262
WST	-0.465629	0.319275	-1.082013*	0.613001	-0.633003*	0.311060
IMM	0.013925	0.121535	-0.092818	0.188505	0.055665	0.159439
C	-93.187400*	47.400430	-201.778800**	75.903080	-87.372110*	48.608630

5. Conclusion and Policy Recommendations

This study examined the influence of national prosperity, official development assistance, water stress, and immunization on population longevity in Somalia using the Autoregressive Distributed Lag (ARDL) approach. The results indicate that there is a long-run relationship between Life Expectancy and the selected explanatory variables. National prosperity, measured by Gross National Income, has a positive and statistically significant influence on Life Expectancy, indicating that improvements in national income are associated with better population longevity. In contrast, Official Development Assistance and Water Stress have negative and statistically significant effects on Life Expectancy. Water stress, in particular, indicates that increasing pressure on available water resources may adversely affect population health and longevity. Immunization, on the other hand, has a positive and statistically significant effect on Life Expectancy, demonstrating the importance of vaccination coverage in improving population health. In the short run, the results indicate that the effects of the explanatory variables vary across periods. Changes in Gross National Income have significant short-run effects, while Official Development Assistance also shows significant but varying effects across current and lagged periods. Water Stress has a significant negative short-run effect, whereas Immunization has a positive but statistically insignificant short-run effect. The negative and statistically significant error correction term confirms the existence of a long-run equilibrium relationship among the variables and indicates that deviations from the long-run equilibrium are corrected over time. Overall, the findings suggest that population longevity in Somalia is influenced by economic prosperity, development assistance, hydrological conditions, and immunization coverage.

Policy Recommendations

To improve population longevity and promote sustainable human development, Somalia needs to strengthen economic prosperity and create conditions that support improvements in household income and living standards. Since national income has a positive and significant long-run relationship with Life Expectancy, policies that promote sustainable economic growth, employment opportunities, income generation, and access to essential social services should be strengthened. Water security should also be given greater priority because Water Stress has a negative and significant effect on Life Expectancy. The government should invest in sustainable water-resource management, expansion of safe water supply, sanitation infrastructure, water conservation, and climate-resilient water systems. These measures would help reduce the health

risks associated with limited access to safe and reliable water resources. Immunization programmes should be strengthened through improved vaccination coverage, accessibility of health services, public awareness, and reliable healthcare delivery systems. The positive and significant long-run effect of Immunization demonstrates that continued investment in vaccination programmes can contribute to improving population longevity. Furthermore, Official Development Assistance should be effectively coordinated and directed toward sustainable health, water, sanitation, and economic development programmes. The negative long-run association between ODA and Life Expectancy highlights the importance of improving the effectiveness, targeting, and sustainability of development assistance so that external resources contribute to strengthening domestic institutions and long-term development capacity.

Limitations and Future Research

This study has some limitations, mainly related to data availability and the relatively limited number of observations. The analysis covers the period from 1987 to 2022 and focuses on four principal determinants of Life Expectancy: Gross National Income, Official Development Assistance, Water Stress, and Immunization. Other potentially important determinants of population longevity, such as healthcare expenditure, poverty, nutrition, sanitation, maternal and child health, environmental pollution, and access to healthcare services, were not included in the model because of data limitations. Another limitation is that Water Stress is used as the main indicator of hydrological security. Future studies could incorporate additional measures of water security, such as access to safe drinking water, sanitation, rainfall variability, drought intensity, and water availability. Future research could also consider additional socioeconomic and health-related variables and employ alternative econometric approaches, including nonlinear ARDL models, to investigate whether the effects of economic, environmental, and health factors on Life Expectancy are asymmetric or nonlinear. Further research could also examine how specific policies related to water security, economic development, immunization, and healthcare investment can contribute to improving population longevity in Somalia.

Author Contributions

CRediT Mohamed Muhumed Hassan: Conceptualization, methodology, data curation, formal analysis, investigation, visualization, writing original draft, writing review and editing, project administration, and correspondence.

Ali Yuusuf Mohamud: Literature review, writing – original draft (Introduction), and writing – review and editing.

Aisha Abdikadir Diriye: Investigation, validation, literature review, and writing – review and editing.

Najma Mukhtar Hassan: Investigation, data interpretation, validation, and writing – review and editing.

Isack Abdi Bilow: Supervision, conceptualization, methodology, validation, and writing – review and editing.

All authors reviewed and approved the final version of the manuscript and agreed to be accountable for their respective contributions.

Ethics and declarations

Ethics approval

Not applicable.

Consent to publish

Not applicable.

Consent to participate

Not applicable.

Competing interests

The authors declare no competing interests.

Clinical trial declaration

Not applicable.

Data availability

The data for this study is available upon request from the authors.

REFERENCES

Abdi, Y. H., Abdi, M. S., Bashir, S. G., Ahmed, N. I., & Abdullahi, Y. B. (2025). The state of public health in Somalia: Top 5 challenges and strategies for improvement. *Public Health Challenges*. https://doi.org/10.1002/puh2.70138

Aksan, A.-M., & Chakraborty, S. (2023). Life expectancy across countries: Convergence, divergence and fluctuations. *World Development, 168*, 106263. https://doi.org/10.1016/j.worlddev.2023.106263

Bendavid, E., & Bhattacharya, J. (2014). The relationship of health aid to population health improvements. *JAMA Internal Medicine, 174*(6), 881-887. https://doi.org/10.1001/jamainternmed.2014.292

Beyene, S. D., & Kotosz, B. (2021). Empirical evidence for the impact of environmental quality on life expectancy in African countries. *Journal of Health and Pollution, 11*(29), 210312. https://doi.org/10.5696/2156-9614-11.29.210312

Bile, A. S., Ali-Salad, M. A., Mahmoud, A. J., Singh, N. S., Abdelmagid, N., Sabahelzain, M. M., Checchi, F., Mounier-Jack, S., & Nor, B. (2024). Assessing vaccination delivery strategies for zero-dose and under-immunized children in the fragile context of Somalia. *Vaccines, 12*(2), 154. https://doi.org/10.3390/vaccines12020154

Burnside, C., & Dollar, D. (2000). Aid, policies, and growth. *American Economic Review*, *90*(4), 847-868. https://doi.org/10.1257/aer.90.4.847

Chewe, M., & Hangoma, P. (2020). Drivers of health in sub-Saharan Africa: A dynamic panel analysis. *Health Policy OPEN, 1*, 100013. https://doi.org/10.1016/j.hpopen.2020.100013

Clemens, M. A., Radelet, S., Bhavnani, R. R., & Bazzi, S. (2011). Counting chickens when they hatch: Timing and the effects of aid on growth. *The Economic Journal*, *122*(561), 590-617. https://doi.org/10.1111/j.1468-0297.2011.02482.x

Cutler, D., Deaton, A., & Lleras-Muney, A. (2006). The determinants of mortality. https://doi.org/10.3386/w11963

Dahir, H. G., Ibrahim, A. J., & Muse, A. H. (2026). Modelling the impact of economic development, health-related factors and political instability on life expectancy in Somalia: an ARDL approach. *Discover Public Health, 23*, 203. https://doi.org/10.1186/s12982-026-01537-6

Deaton, A. (2003). Health, inequality, and economic development. *Journal of Economic Literature*, *41*(1), 113-158. https://doi.org/10.1257/jel.41.1.113

Desai, H. (2020). *States of fragility and official development assistance*. Organisation for Economic Co-operation and Development.

Dhungana, B. R., Singh, J. K., & Dhungana, S. (2024). Life expectancy and health care spending in South Asia: An econometric analysis. *PLOS ONE, 19*(12), e0310153. https://doi.org/10.1371/journal.pone.0310153

FAO, & UN-Water. (2024). *Progress on the level of water stress: Global status and acceleration needs for SDG indicator 6.4.2*. Food and Agriculture Organization of the United Nations. https://doi.org/10.4060/cd2179en

Fuente, D., Allaire, M., Jeuland, M., & Whittington, D. (2020). Forecasts of mortality and economic losses from poor water and sanitation in sub-Saharan Africa. *PLOS ONE, 15*(3), e0227611. https://doi.org/10.1371/journal.pone.0227611

Ge, X., & Wu, H. (2025). Public health policy pathways for balancing ecological challenges, healthcare systems, and social development in rapidly urbanizing economies. *Frontiers in Public Health, 13*, 1716258. https://doi.org/10.3389/fpubh.2025.1716258

Grossman, M. (1972). On the concept of health capital and the demand for health. *Journal of Political Economy, 80*(2), 223-255. https://doi.org/10.1086/259880

Hauck, K., Martin, S., & Smith, P. C. (2016). Priorities for action on the social determinants of health: Empirical evidence on the strongest associations with life expectancy in 54 low-income countries, 1990-2012. *Social Science & Medicine, 167*, 88-98. https://doi.org/10.1016/j.socscimed.2016.08.035

Kaluarachchi, S., & Jayathilaka, R. (2026). Impact of socioeconomic factors on life expectancy: A global perspective across income levels. *Sustainable Development*. https://doi.org/10.1002/sd.70702

Kontodimopoulos, N. (2022). The association between social development and population health: A cross-sectional study across countries of different economic growth. *Research in Health Services & Regions, 1*, 2. https://doi.org/10.1007/s43999-022-00003-5

Liou, L., Joe, W., Kumar, A., & Subramanian, S. V. (2020). Inequalities in life expectancy: An analysis of 201 countries, 1950-2015. *Social Science & Medicine, 253*, 112964. https://doi.org/10.1016/j.socscimed.2020.112964

Majeed, M. T., & Luni, T. (2026). Assessing the effects of water quality on population health outcomes: Does the level of economic development matter? *Journal of the Knowledge Economy, 17*, 4175-4212. https://doi.org/10.1007/s13132-026-03197-y

Mohamed, A. A., Mohamed, S. N., Weyrah, I. M., Isse, M. D., & Husein, I. A. (2025). Determinants of economic well-being and human development in Somalia: A dual analysis of GDP per capita and life expectancy. *Cogent Economics & Finance, 13*(1), 2513486. https://doi.org/10.1080/23322039.2025.2513486

Mohamoud, S. A., Ali-Salad, M. A., Bile, A. S., Singh, N. S., Mahmud, A. J., & Nor, B. (2024). Determinants and prevalence of zero-dose children in Somalia: Analysis of the 2020 Health Demographic Survey data. *PLOS Global Public Health, 4*(7), e0002612. https://doi.org/10.1371/journal.pgph.0002612

Mondal, M. N. I., & Shitan, M. (2014). Relative importance of demographic, socioeconomic and health factors on life expectancy in low- and lower-middle-income countries. *Journal of Epidemiology, 24*(2), 117-124. https://doi.org/10.2188/jea.JE20130059

Morrison, J., & Malik, S. M. M. R. (2023). Population health trends and disease profile in Somalia 1990-2019, and projection to 2030: Will the country achieve sustainable development goals 2 and 3? *BMC Public Health, 23*, 1-9. https://doi.org/10.1186/s12889-022-14960-6

Nwude, E. C., Ugwoke, R. O., Uruakpa, P. C., Ugwuegbe, U. S., & Nwonye, N. G. (2020). Official development assistance, income per capita and health outcomes in developing countries: Is Africa different? *Cogent Economics & Finance, 8*(1), 1774970. https://doi.org/10.1080/23322039.2020.1774970

Pesaran, M. H., Shin, Y., & Smith, R. J. (2001). Bounds testing approaches to the analysis of level relationships. *Journal of Applied Econometrics, 16*(3), 289-326. https://doi.org/10.1002/jae.616

Preston, S. H. (1975). The changing relation between mortality and level of economic development. *Population Studies*, *29*(2), 231-248. https://doi.org/10.1080/00324728.1975.10410201

Pritchett, L., & Summers, L. H. (1996). Wealthier is healthier. *The Journal of Human Resources*, *31*(4), 841. https://doi.org/10.2307/146149

Rajan, R. G., & Subramanian, A. (2008). Aid and growth: What does the cross-country evidence really show? *Review of Economics and Statistics*, *90*(4), 643-665. https://doi.org/10.1162/rest.90.4.643

Salami, D., Shaaban, A. N., & Martins, M. do R. O. (2019). Africa rising, a narrative for life expectancy gains? Evidence from a health production function. *Annals of Global Health, 85*(1), 63. https://doi.org/10.5334/aogh.2307

Shattock, A. J., Johnson, H. C., Sim, S. Y., Carter, A., Lambach, P., Hutubessy, R. C. W., ... Bar-Zeev, N. (2024). Contribution of vaccination to improved survival and health: Modelling 50 years of the Expanded Programme on Immunization. *The Lancet, 403*(10441), 2307-2316. https://doi.org/10.1016/S0140-6736(24)00850-X

Stojanov, R., Nemec, D., & Zidek, L. (2019). Evaluation of the long-term stability and impact of remittances and development aid on sustainable economic growth in developing countries. *Sustainability, 11*(6), 1538. https://doi.org/10.3390/su1106153 8

Warsame, A., Frison, S., & Checchi, F. (2023). Drought, armed conflict and population mortality in Somalia, 2014-2018: A statistical analysis. *PLOS Global Public Health, 3*(4), e0001136. https://doi.org/10.1371/journal.pgph.0001136

World Bank. (2024). *Data for Sub-Saharan Africa, Somalia*. https://data.worldbank.org/?locations=ZG-SO

World Bank. (2026). *Life expectancy at birth, total (years)*. https://data.worldbank.org/indicator/SP.DYN.LE00.IN

World Health Organization. (2024). *World health statistics 2024: Monitoring health for the SDGs*. WHO.

World Health Organization. (2025). *WHO's strategic objectives: Somalia country update*. WHO.

World Health Organization, & UNICEF. (2026). *Somalia: WHO and UNICEF estimates of immunization coverage, 2025 revision*.

Pesaran, M. H., Shin, Y., & Smith, R. J. (2001). Bounds testing approaches to the analysis of level relationships. *Journal of Applied Econometrics*, *16*(3), 289–326. https://doi.org/10.1002/jae.616