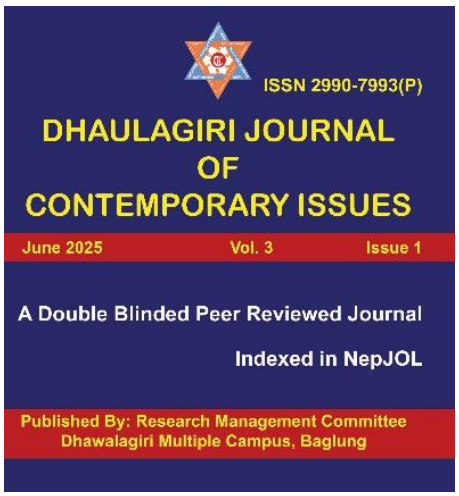

ISSN: 2990-7993(P)

Dhaulagiri Journal of Contemporary Issues
Vol 3, Issues 1
June, 2025

DOI: https://doi.org/10.3126/djci.v3i1.79681

Published by: Research Management Committee,
Dhawalagiri Multiple Campus, Baglung

Home Page: https://dmcjournal.edu.np/index.php/DWJCI

Effects of Health Expenditure on Life Expectancy in Nepal

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Abstract

This study examines the long-run impact of health expenditure on life expectancy in Nepal, a low-income country with unique socio-economic and public health challenges. Using annual time-series data from 2001 to 2021, the research employs the Dynamic Ordinary Least Squares (DOLS) method to estimate long-term elasticities and conducts Granger causality tests to explore predictive relationships. The analysis controls for GDP per capita, educational attainment, and access to safe drinking water. The findings reveal that a 1% increase in health expenditure per capita is associated with a 0.031% rise in life expectancy ($p = 0.0111$), while educational attainment exerts a stronger effect, with a 0.349% increase ($p = 0.0018$). Surprisingly, GDP per capita shows a negative coefficient (-0.255%, $p = 0.006$), possibly reflecting income inequality and urban-rural disparities in health access. Safe water access also has a modest positive effect (0.024%, $p = 0.018$). Granger causality tests indicate that life expectancy significantly predicts future gains in GDP and education, highlighting a feedback loop between health and development. The Wald test confirms the joint significance of all explanatory variables ($p < 0.01$), and diagnostic tests validate the model's robustness. These results underscore the importance of targeted health and education investments and call for inclusive policies to ensure equitable health outcomes across Nepal.

Keywords: Dynamic ordinary least squares, health expenditure, life expectancy, public health, socioeconomic factors

Article Information

Received: 9 February, 2025 **Reviewed:** 12 February, 2025 - 25 March, 2025 Revised: 26 March, 2025- 1 May, 2025
Accepted: 5 May, 2025 **Published:** 2 June, 2025

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Introduction

Life expectancy is a crucial indicator of a nation's overall health and well-being, reflecting not only the health outcomes of its population but also the effectiveness of its health system and socioeconomic policies. Studies by Kiross et al. (2020) and Owusu et al. (2021) provide empirical evidence from sub-Saharan Africa showing that increased health expenditure significantly reduces infant and adult mortality rates, thereby enhancing life expectancy. These findings align with broader economic literature that links public health investment to improved human capital outcomes in developing regions. Health expenditure, in particular, has been identified as a key driver of life expectancy, influencing mortality rates and general health conditions across various populations and regions (Behera & Dash, 2020; Radmehr & Adebayo, 2022). This relationship is of interest not only to policymakers aiming to improve public health but also to researchers focused on understanding how investments in healthcare impact human longevity (Lone et al., 2021).

Empirical studies, such as those by Jakovljevic et al. (2020) and Al-Azri et al. (2020), underscore the positive association between health expenditure and life expectancy; however, the strength and consistency of this relationship differ across economic contexts. In high-income countries, greater resource availability and system efficiency often yield more predictable health gains, whereas in lower-income economies, structural limitations—such as inefficiencies in public health delivery or unequal access—can weaken the effectiveness of increased spending. For instance, high-income countries show a stronger correlation between health spending and life expectancy due to more efficient healthcare systems and resource availability (Freeman et al., 2020). While health expenditure plays a critical role in shaping life expectancy, it does not operate in isolation. Other socioeconomic and environmental factors—such as income levels, access to safe water, and educational attainment—also exert substantial influence on population health outcomes and should be considered to understand the broader determinants of longevity. However, in low- and middle-income countries, limited financial resources often hinder the ability of healthcare expenditure to significantly influence life expectancy, despite the potential for considerable health improvements with increased spending (Rahman et al., 2022; Azam et al., 2023; Kumar, & Yadav,2024).

Beyond health expenditure, factors such as GDP per capita, access to clean water, and education level play essential roles in shaping life expectancy. These variables not only have independent effects but may also interact with health expenditure in synergistic or moderating ways—for instance, higher income levels can improve the efficiency of health spending through better infrastructure, while education enhances health literacy, enabling individuals to make more effective use of health services. Similarly, access to clean water reduces disease burdens, thereby increasing the return on investments in healthcare.

Studies have shown that higher GDP per capita is typically associated with longer life expectancy due to better living standards and access to healthcare (He & Li, 2020). Similarly, access to clean water is fundamental in reducing preventable diseases, thus positively influencing life expectancy (Nketiah-Amponsah, 2019; Osabohien et al., 2021). Education is another critical factor, as it enhances individuals' health awareness and promotes healthier lifestyles (Alimi et al., 2023; Karma, 2023).

Although health expenditure appears to be a robust predictor of life expectancy, some researchers argue that factors like income inequality and environmental conditions also contribute significantly to life expectancy variations (Breyer & Felder, 2006; Chetty et al., 2016). For example, countries with high environmental pollution often face challenges in translating health expenditures into better health outcomes due to increased disease burdens related to air and water quality (Rjoub et al., 2021). Additionally, disparities in income and access to healthcare can undermine the effectiveness of health expenditures, leading to inequitable health outcomes within a population (Lubitz et al., 2003).

Given these complexities, this study aims to explore the effects of health expenditure on life expectancy in Nepal. It also examines the influence of key socioeconomic variables—GDP per capita, access to clean water and education level—to provide a more comprehensive understanding of the determinants of longevity. By examining these factors together, this research seeks to provide a comprehensive understanding of the determinants of life expectancy and to identify which aspects of health spending and socioeconomic resources most effectively contribute to improved health outcomes (Opaiţ, 2017; Owusu et al., 2021). This understanding can guide policymakers in prioritizing health and social investments to maximize the positive impacts on population health and longevity.

Literature Review

Current Health Expenditure and Life Expectancy

Health expenditure and life expectancy has been extensively studied, highlighting a complex interplay of economic, environmental, and social factors. Health expenditure, as a critical component of health systems, is widely recognized as influencing health outcomes, with several studies suggesting a direct impact on life expectancy (Kiross et al., 2020; Owusu et al., 2021). Kiross et al. (2020) found that increased health spending in sub-Saharan Africa significantly reduced infant mortality rates, underscoring the importance of investment in healthcare for improving overall population health. Similarly, Owusu et al. (2021) argued that sustainable health expenditures are essential for reducing mortality rates, further linking financial investment in healthcare to improved health outcomes.

Jakovljevic et al. (2020) noted disparities in healthcare expenditure efficiency across leading Asian economies, particularly between countries that are members of the Organization for Economic Co-operation and Development (OECD) and those that are not. They highlighted the necessity for economic reforms to improve the efficiency of health spending in non-OECD nations.

Similarly, Behera and Dash (2020) observed that health expenditure effectively improved health outcomes in Southeast Asia, although socioeconomic inequalities continued to pose challenges. Al-Azri et al. (2020) found that health expenditure in Oman positively influenced health outcomes, but they emphasized that the results varied based on expenditure allocation and access to health services.

The link between healthcare spending and health outcomes is also explored in Lone et al.'s (2021) study of the Indian healthcare system, which used cointegration analysis to show a long-term relationship between health expenditure and health outcomes. In Mediterranean countries, Radmehr and Adebayo (2022) confirmed that increased health spending correlates with higher life expectancy, though economic stability and governance were critical in determining the efficiency of such expenditures.

Alimi et al. (2023) further established that public policy directly impacts health outcomes, with health expenditure playing a central role in increasing life expectancy and reducing child mortality in Nigeria. Similar findings were reported by Nketiah-Amponsah (2019) for sub-Saharan Africa, where investments in healthcare have been shown to improve health outcomes across low-income regions. These studies collectively emphasize that health expenditures, particularly when directed toward essential services, can significantly enhance life expectancy, especially in developing regions with limited healthcare resources.

GDP Per Capita and Life Expectancy

Freeman et al. (2020) explored the role of income in life expectancy, examining Brazil, Ethiopia, and the United States. They concluded that while income disparities contribute to differences in life expectancy, efficient health systems can offset some of these inequalities. Azam et al. (2023) studied determinants of life expectancy in Pakistan and observed that while health expenditure and economic factors were influential, environmental quality and educational access also played a substantial role. Rahman et al. (2022) similarly found that life expectancy in highly polluted countries is adversely impacted by environmental degradation, despite health expenditures.

Chetty et al. (2016) investigated the U.S. context, revealing substantial disparities in life expectancy based on income levels. They concluded that increased health spending could improve life expectancy, but only when it is accessible to lower-income populations. Supporting this view, Breyer and Felder (2006) calculated healthcare costs in Germany, finding that expenditures toward end-of-life care play a substantial role in extending life expectancy. Lubitz et al. (2003) also highlighted the high healthcare spending among the elderly in the U.S., linking it to the country's high life expectancy.

The importance of economic growth in determining life expectancy is further evidenced in He and Li's (2020) analysis, which suggests a positive association between economic growth and life expectancy, as wealthier nations can allocate more resources toward health services. This is corroborated by Karma (2023), who demonstrated that socioeconomic factors, including economic stability and education levels, significantly impact life expectancy across Southeastern European countries.

Rjoub et al. (2021) analyzed data from Turkey, showing that economic growth, reduced carbon emissions, and improved healthcare accessibility are essential in promoting life expectancy. In contrast, Osabohien et al. (2021) found that environmental degradation adversely affects life expectancy in Nigeria, underscoring the need for sustainable environmental policies. Opaiţ (2017) extended these findings to the U.S., where increased healthcare spending improved life expectancy but was less effective when environmental and social challenges were unaddressed.

Collectively, this body of literature demonstrates that health expenditure has a notable impact on life expectancy across different regions. However, it is increasingly clear that economic growth, environmental quality, and equitable access to healthcare services and education significantly influence the efficiency and impact of health spending on life expectancy. This broader perspective is vital for crafting effective health policies that enhance longevity and improve population well-being.

Education Attainment and Life Expectancy

As mortality rates have declined, populations have seen notable increases in educational attainment (Lutz et al. 2014). For example, from 1970 to 2009, the average educational attainment rose by 3.6 years among people aged 25 and older across 175 countries (Gakidou et al. 2010). Extensive research highlights the strong influence of socioeconomic resources on a variety of health outcomes, framing socioeconomic conditions as a "fundamental cause" of health and mortality inequalities (Link and Phelan 1995). Numerous studies indicate that those with higher education tend to benefit most and earliest from key factors driving reductions in mortality, especially concerning cardiovascular disease risk factors (Mirowsky and Ross 2003; Hummer and Lariscy 2011).

While the direct link between education and health outcomes remains debated, education tends to improve income, job prospects, and health literacy, thereby influencing health indirectly (Kaplan et al., 2014). While some evidence suggests a reasonable basis for assuming a direct causal effect (Geyer and Peter 2000; Lleras-Muney 2005; Lutz and Skirbekk 2014), it appears that the link between education and mortality primarily operates indirectly, with education serving as a gateway to other determinants of health and longevity (Arendt 2005; Clark and Royer 2013; Kröger et al. 2015; Kilpi et al. 2016). As Hayward et al. (2015) put it, "...there is no inherent causal association between educational attainment and adult mortality; instead, the causal association is dependent upon time, place, and social environment under study."

Assess safe water and Life Expectancy

Access to safe and clean drinking water is essential for public health and longevity, as inadequate access increases the risk of waterborne diseases and reduces life expectancy. Research indicates that minerals such as calcium and magnesium in drinking water lower risks of diseases, including breast cancer, highlighting that both water availability and quality are crucial for health (Yang et al., 2000). Li et al. (2021) found that access to clean water reduces mortality, especially in low-income areas, by decreasing exposure to infectious pathogens. Kim et al. (2022) demonstrated that inadequate access to safe drinking water contributes to higher rates of chronic illness and infant mortality, underscoring its direct impact on life expectancy. Environmental factors such as climate change and pollution also impact water quality, which in turn affects public health, as noted by Khan et al. (2021). Improvements in water infrastructure, as suggested by Muthusamy et al. (2016), can mitigate these risks and support longevity in underserved regions by providing safer water sources.

Methods

Data Source and Variables

This study utilizes national-level annual time-series data for Nepal from 2001 to 2021, sourced from the World Development Indicators (WDI) database of the World Bank. The selection of Nepal reflects the study's focus on understanding health outcomes in a low-income South Asian context, where public health infrastructure and economic constraints shape the effectiveness of health investments. The World Bank was chosen as the data source

due to its consistency, transparency, and comparability across time. The variables were selected based on theoretical models of health production and empirical studies in development economics that emphasize the multidimensional drivers of life expectancy, including public investment, economic capacity, environmental health, and human capital development. The study includes the following variables:

i. **Life Expectancy (LNLE):** The natural logarithm of life expectancy at birth, measured in total years.
ii. **Current Health Expenditure (LNHE):** The natural logarithm of health expenditure per capita in current US dollars.
iii. **GDP per Capita (LNGDP):** The natural logarithm of GDP per capita, adjusted to constant 2015 US dollars.
iv. **Educational Attainment (LNEA):** The natural logarithm of the percentage of the population aged 25 and above with at least primary education.
v. **Safe Water Access (LNSW):** The natural logarithm of the percentage of the population with access to safely managed drinking water services.

Econometric Analysis

to ensure linearity and reduce heteroscedasticity, all variables were transformed into their natural logarithmic forms. To assess the suitability of time-series modeling, the Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) tests were applied to confirm stationarity, a necessary condition for cointegration analysis. Upon confirming that the variables are integrated of order one, the Johansen cointegration test was employed, revealing a long-run equilibrium relationship among the variables. Given this cointegration, the Dynamic Ordinary Least Squares (DOLS) method was used to estimate long-run elasticities, correcting for endogeneity and serial correlation by incorporating leads and lags of the differenced independent variables.

Model Specification

The general form of the DOLS regression model for this analysis is specified as follows:

$$LNLE_t=\beta_0+\beta_1 LNHE_t+\beta_2 LNGDP_t+\beta_3 LNEA_t+\beta_4 LNSW_t+\sum_{j=-q}^{q} \alpha j \Delta X_{t-j} + \epsilon_t$$

Where:

$LNLE_t$: Log of life expectancy in year t.

$LNHE_t$: Log of current health expenditure per capita in year t.

$LNGDP_t$: Log of GDP per capita in year t.

$LNEA_t$: Log of educational attainment in year t.

$LNSW_t$: Log of access to safe water in year t.

$\Delta X_{t-j:}$ First-differenced independent variables included as leads and lags to account for possible endogeneity.

q: Number of leads and lags chosen based on information criteria (such as AIC or BIC) to ensure model stability.

ϵ_t: Error term assumed to be normally distributed.

The results from the DOLS model provide long-run elasticity estimates, indicating how a one percent changes in each independent variable—health expenditure, GDP per capita, educational attainment, and access to safe water—affect life expectancy in Nepal. The coefficient for health expenditure, for instance, reflects the direct long-term effect of increased investment in healthcare on population longevity, while other coefficients reveal the broader socio-economic determinants of health outcomes. To assess the robustness of these long-run relationships, the Hansen Parameter Instability Test was applied, confirming that the model's parameters remained stable over time despite potential structural changes. The Wald Test further validated the joint statistical significance of the regressors, justifying their inclusion in the model. Granger causality tests were used to explore directional relationships, identifying predictive links between life expectancy and its determinants. Additionally, the Jarque-Bera test confirmed the normality of residuals, supporting the reliability of statistical inferences. All econometric analyses were conducted using EViews 12, which offered a comprehensive environment for implementing the DOLS method along with essential diagnostic tools.

Results

Descriptive Statistics

Log-transforming variables in econometric analysis stabilize variance, making relationships between variables linear and easier to interpret. This approach also normalizes data, reduces skewness, and allows for the interpretation of coefficients as elasticities or percentage changes, enhancing economic insights. Table 1 provides descriptive statistics for essential health and economic indicators.

Table 1

Summary Statistics of Health and Economic Indicators

	LNLE	LNHE	LNGDP	LNEA	LNSW
Mean	4.203223	3.291643	6.628437	3.670392	3.237985
Median	4.209353	3.526361	6.617420	3.676396	3.316385
Maximum	4.242161	4.174387	6.967425	3.936205	3.396609
Minimum	4.147316	2.302585	6.321430	3.431727	2.777384
Std. Dev.	0.028472	0.637076	0.220361	0.132745	0.180653
Skewness	-0.572732	-0.267379	0.108828	0.067592	-1.355633
Kurtosis	2.343435	1.576894	1.647981	2.455244	3.601407
Observations	21	21	21	21	21

Table 1 summarizes the central tendencies and distributional characteristics of key variables related to life expectancy in Nepal from 2001 to 2021. The relatively stable mean and median values of life expectancy (LNLE) and GDP per capita (LNGDP) suggest consistent improvements in health and economic conditions during the study period. Notably, the standard deviation for health expenditure (LNHE) is higher than for other variables, indicating greater variability in annual health investments. This fluctuation may have influenced the uneven impact of health expenditure on life expectancy over time. Similarly, the negative skewness observed in safe water access (LNSW) points to occasional shortfalls in service provision, which may have posed public health risks in certain years. The kurtosis values for all variables remain below 3, suggesting a lack of extreme outliers and reinforcing the statistical reliability of the data for econometric modeling. While these descriptive statistics offer valuable preliminary insights, the table does not account for subgroup differences—such as regional or income-level variations—which may influence the interpretation of how these socioeconomic factors affect life expectancy. This analysis supports the relevance of health expenditure, economic performance, education, and environmental quality as potential long-run determinants of life expectancy in Nepal.

Covariance Analysis of Variables

Understanding the interrelationship between variables through covariance analysis provides insights into how changes in one economic indicator may align with others. Table 2 shows the covariance and correlation coefficients among key health and economic variables, offering a foundation for evaluating the strength and direction of these relationships.

Table 2 presents the Pearson correlation coefficients among the study variables, revealing strong positive associations between life expectancy (LNLE), health expenditure per capita (LNHE), and GDP per capita (LNGDP). These bivariate relationships suggest that improvements in economic indicators are often accompanied by gains in health outcomes. However, the negative correlation observed between access to safe water (LNSW) and variables such as LNHE and LNLE indicates that inconsistent or inadequate water access may offset some of the health gains associated with increased spending or economic growth, underscoring the need for integrated public health and

infrastructure policies.

Table 2

Covariance and Correlation Coefficients among Key Variables

Correlation	LNLE	LNHE	LNGDP	LNEA	LNSW
LNLE	1.000000				
LNHE	0.953307	1.000000			
	0.0000	-----			
LNGDP	0.942686	0.976801	1.000000		
	0.0000	0.0000	-----		
LNEA	0.918603	0.902136	0.908287	1.000000	
	0.0000	0.0000	0.0000	-----	
LNSW	-0.579273	-0.645952	-0.759278	-0.624618	1.000000
	0.0059	0.0016	0.0001	0.0025	-----

While these correlations offer useful preliminary insights, it is important to emphasize that correlation does not imply causation. These results reflect associations rather than net effects, and do not control for potential confounding variables such as education or environmental factors. For example, the observed correlations between LNHE and LNGDP may be influenced by shared underlying drivers or policy environments. Moreover, to more rigorously assess the risk of multicollinearity, particularly between highly correlated variables like GDP and health expenditure, the study incorporates Variance Inflation Factor (VIF) analysis in the regression diagnostics. All VIF values fall below the conventional threshold, suggesting that multicollinearity does not pose a significant threat to the estimation results.

Trends in Health and Economic Indicators

Visualizing trends in health and economic indicators over time is essential for understanding their evolving impacts on population well-being and economic outcomes. Figure 1 illustrates the trends in key health and economic indicators, offering a longitudinal perspective on these variables.

Figure 1

Trends in Health and Economic Indicators

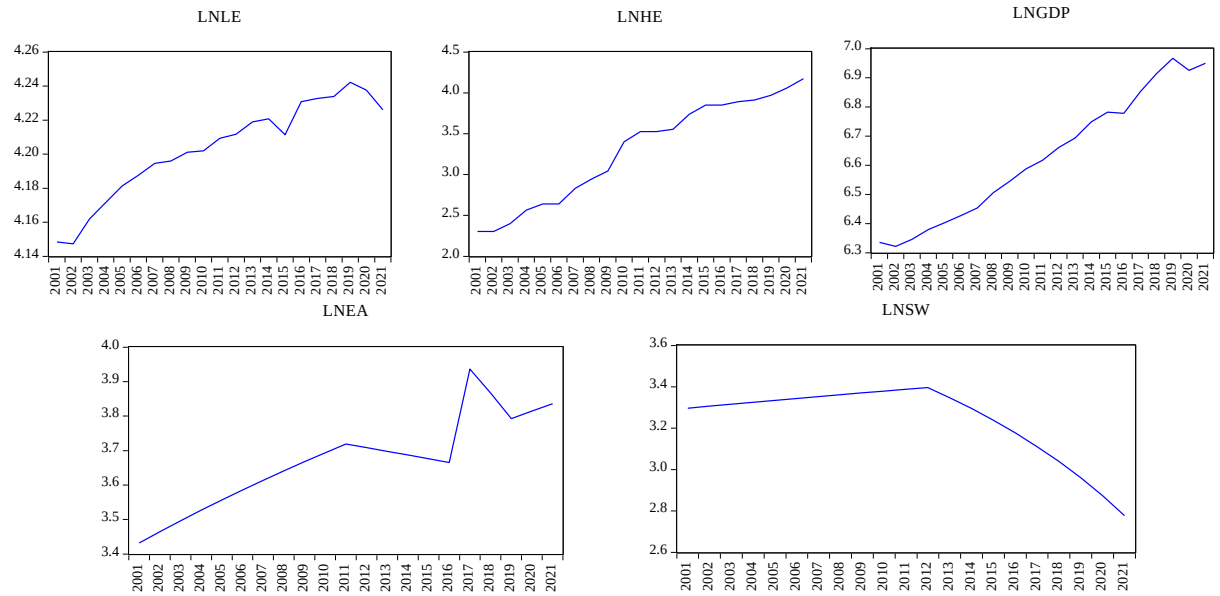

Figure 1 illustrates the temporal trends in life expectancy, GDP per capita, health expenditure, education, and access to safe water in Nepal from 2001 to 2021. Both GDP per capita and health expenditure show steady upward trends over the period, reflecting broader economic growth and increasing national investment in healthcare. Life expectancy also rises over time, generally aligning with improvements in these economic indicators, suggesting that increased public spending and economic development may have contributed to longer lifespans. However, there are periods where this relationship appears less consistent—such as brief phases where life expectancy levels off despite rising GDP or health expenditure—indicating that other contextual factors (e.g., unequal access, health system inefficiencies, or external shocks) may have moderated the impact. These divergences highlight the importance of considering additional determinants like education and environmental quality when evaluating the effectiveness of economic progress in delivering public health gains. Overall, the figure visually supports the study's premise that sustained improvements in economic and social investments are linked to better health outcomes, while also pointing to the complexity of these relationships.

Unit Root Test Results

Testing for unit roots in time series data is a fundamental step in econometric analysis, ensuring that variables are stationary and suitable for regression without spurious results. Table 3 presents the results of the unit root tests for health and economic indicators at level and first difference.

Table 3

Unit Root Test Results for Health and Economic Indicators

Unit Root Test Table (PP)						
At Level		**LNLE**	**LNHE**	**LNGDP**	**LNEA**	**LNSW**
With Const.	t-Statistic	-3.2661**	-0.7847	0.2299	-1.4907	2.8548
With C.& T.	t-Statistic	0.0265	-1.4730	-3.6299*	-3.1498	1.6294
At First Diff.		**d(LNLE)**	**d(LNHE)**	**d(LNGDP)**	**d(LNEA)**	**d(LNSW)**
With Const.	t-Statistic	-4.1572***	-3.9293***	-5.0809***	-9.2025***	0.2449
With C. & T.	t-Statistic	-5.7625***	-5.7870***	-4.7676***	-10.8759***	-1.9893
Unit Root Test Table (ADF)						
At Level		**LNLE**	**LNHE**	**LNGDP**	**LNEA**	**LNSW**
With Const.	t-Statistic	-2.1506	-0.7415	1.0376	-1.5844	-0.1968
With C. & T.	t-Statistic	-1.1682	-1.4086	-3.8314**	-3.2894*	0.0101
At First Diff.		**d(LNLE)**	**d(LNHE)**	**d(LNGDP)**	**d(LNEA)**	**d(LNSW)**
With Const.	t-Statistic	-4.1572***	-3.9267***	-3.2420**	-5.0870***	0.2008
With C. & T.	t-Statistic	-5.4636***	-4.1328**	-2.0626	-10.9022***	-1.9945

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

Table 3, which presents unit root test results for health and economic indicators, both the Phillips-Perron (PP) and Augmented Dickey-Fuller (ADF) tests were conducted at level and first difference. For instance, results from the PP test indicate that life expectancy (LNLE) shows stationarity at level with constant but not when a trend is added. In contrast, GDP per capita (LNGDP) and educational attainment (LNEA) require first differencing to achieve stationarity, pointing to their potential for integration in cointegration tests.

The results at first difference suggest that each of these economic indicators (such as health expenditure and GDP per capita) achieves stationarity after differencing, thus supporting further analysis such as cointegration tests to explore long-term relationships. This aligns with economic theories that variables like health expenditure and life expectancy tend to exhibit trends over time, as influenced by continuous policy changes and socioeconomic development.

Such findings imply that health expenditure impacts life expectancy in the long term, but short-term deviations may not immediately influence this outcome, highlighting the need for a sustained policy focus on health

investment.

Table 4

Unit Root Test Results Table (KPSS)

Null Hypothesis: the variable is stationary

At Level		LNLE	LNHE	LNGDP	LNEA	LNSW
With Const.	t-Statistic	0.6081**	0.6224**	0.6242**	0.6035**	0.4504*
With C.& T.	t-Statistic	0.1777**	0.1560**	0.1567**	0.0776	0.1731**
First Diff.		d(LNLE)	d(LNHE)	d(LNGDP)	d(LNEA)	d(LNSW)
With Const.	t-Statistic	0.4048*	0.1551	0.1847	0.5000**	0.5499***
With C. & T.	t-Statistic	0.2688***	0.1321*	0.1657**	0.5000***	0.1516**

Note: ∗, ∗∗ and ∗∗∗ denote significance at the 10%, 5% and 1% levels, respectively.

Table 4 provides the KPSS (Kwiatkowski-Phillips-Schmidt-Shin) test results, which complement the ADF and PP tests by testing the opposite hypothesis—that the series is stationary rather than non-stationary. In this test, stationarity is assumed under the null hypothesis, making it useful for confirming the stationarity results obtained from the other unit root tests.

The KPSS test results in Table 4 for health and economic indicators suggest that life expectancy (LNLE), health expenditure per capita (LNHE), GDP per capita (LNGDP), educational attainment (LNEA), and access to safe water (LNSW) generally exhibit stationarity when the test is conducted at level with constant and trend. This result is particularly relevant as it implies that these variables do not exhibit random-walk behavior but rather have a mean-reverting process over time. Stationarity at level suggests that any shocks to these indicators are likely temporary, and the variables will revert to their mean levels.

This finding has significant implications for economic policy, as it indicates that improvements in health expenditure, GDP per capita, or educational attainment could have stable, long-term effects on life expectancy. Policymakers can interpret this as an incentive to make sustained investments in these areas, knowing that short-term fluctuations will not permanently affect the broader economic and health outcomes. The KPSS results, therefore, strengthen the reliability of using these variables in long-term econometric models without differencing, especially for studying their potential causal effects on life expectancy.

Table 5

Var Lag Length Criteria

Lag	LogL	LR	FPE	AIC	SC	HQ
0	139.8177	NA	9.61e-13	-13.48177	-13.23283	-13.43317
1	254.1838	160.1126*	1.39e-16*	-22.41838*	-20.92478*	-22.12681*

Table 5 presents the results of the lag length selection using a Vector Autoregression (VAR) framework, where lag 1 emerged as the optimal choice across multiple information criteria, including AIC, FPE, SC, and HQ. Although the primary estimation in this study uses the Dynamic Ordinary Least Squares (DOLS) model rather than VAR, the VAR-based lag selection was conducted as a preliminary diagnostic to guide the inclusion of leads and lags in the DOLS specification. This approach ensures consistency in capturing the short-run dynamics among the variables and supports model parsimony.

Table 6

Johansen Cointegration Test

Hypothesized No. of CE(s)	Trace Statistic	0.05 Critical Value	Max-Eigen Statistic	0.05 Critical Value
None *	115.5336	69.81889	62.52758	33.87687
At most 1 *	53.00606	47.85613	27.96684	27.58434
At most 2	25.03922	29.79707	15.87829	21.13162
At most 3	9.160929	15.49471	5.308880	14.26460
At most 4 *	3.852049	3.841466	3.852049	33.87687

The Johansen cointegration test results in Table 6 confirm the existence of stable long-term equilibrium relationships among the key variables: life expectancy, health expenditure, GDP per capita, educational attainment, and access to safe drinking water. The presence of at least two statistically significant cointegrating equations—supported by both Trace and Max-Eigen statistics—rejects the null hypothesis of no cointegration, thereby validating the assumption that these variables move together over time rather than drifting apart. This finding is particularly crucial for the research aim, as it highlights that health expenditure and education, in particular, share a strong and sustained equilibrium relationship with life expectancy, reinforcing their foundational roles in shaping long-run health outcomes in Nepal.

Cointegration also provides the necessary statistical foundation for applying the Dynamic Ordinary Least Squares (DOLS) method, which is specifically designed to estimate long-run relationships in the presence of cointegrated variables. By confirming that these variables converge toward a shared trajectory, the test supports the use of DOLS to generate unbiased and consistent elasticity estimates that capture the true long-term impact of public investments in health and education. From a policy perspective, this means that improvements in health and education are not just beneficial in the short run, but are deeply embedded in the structural determinants of life expectancy, highlighting the importance of sustained and coordinated policy interventions in these sectors to achieve meaningful health outcomes.

Table 7

Results of Dynamic Least Squares (DOLS) Dependent Variable: LNLE

Variable	Coefficient	Std. Error	t-Statistic	Prob.
LNHE	0.031056	0.000541	57.38443	0.0111
LNGDP	-0.254548	0.002381	-106.8915	0.0060
LNEA	0.348876	0.000999	349.2517	0.0018
LNSW	0.024112	0.000680	35.44567	0.0180
C	4.419732	0.013840	319.3413	0.0020
R-squared	1.000000	Mean dependent var		4.208100
Adjusted R-squared	0.999999	S.D. dependent var		0.023182
S.E. of regression	2.60E-05	Sum squared resid		6.77E-10
Long-run variance	3.03E-10			

Table 7 presents the DOLS estimation results, revealing that health expenditure and educational attainment have strong, positive, and statistically significant long-term effects on life expectancy in Nepal. A 1% increase in health spending is associated with a 0.031% rise in life expectancy, while a similar increase in education levels leads to an even larger 0.349% improvement, underscoring the crucial role of social investments in shaping health outcomes. Unexpectedly, GDP per capita shows a negative relationship with life expectancy, which contradicts

theoretical expectations. This may be explained by Nepal's structural inequalities, including urban-rural disparities, unequal income distribution, and the concentration of economic gains among higher-income groups, which may prevent broader segments of the population from benefiting equally in terms of health improvements. The model also reports an exceptionally high R^2 value of 1.000, suggesting a near-perfect fit. While supportive of a strong explanatory model, this result should be interpreted with caution, as it may reflect over fitting or limitations related to the small sample size. Despite passing key diagnostic tests, such precision in a limited dataset calls for careful generalization and points to the need for future studies with larger, disaggregated data to validate and expand upon these findings.

Conversely, GDP per capita (LNGDP) shows a negative coefficient (-0.2545), indicating that a 1% increase in GDP per capita correlates with a 0.25% decrease in life expectancy. This unexpected direction might reflect socioeconomic inequalities, where economic growth does not evenly translate into health benefits for all. Safe water access (LNSW) has a positive coefficient (0.0241), suggesting a 0.02% increase in life expectancy for each 1% increase in safe water access. These results underscore that health and educational investments have the most substantial positive impacts on life expectancy, while economic growth, without equitable distribution and accessible health resources, may not directly benefit public health outcomes in Nepal.

Table 8

Cointegration Test - Hansen Parameter Instability

Series: LNLE LNHE LNGDP LNEA LNSW		Null hypothesis: Series are cointegrated		
Lc statistic	Stochastic Trends (m)	Deterministic Trends (k)	Excluded Trends (p2)	Prob.*
0.023030	4	0	0	> 0.2

*Hansen (1992b) Lc(m2=4, k=0) p-values, where m2=m-p2 is the number of stochastic trends in the asymptotic distribution

Table 8 presents the results of the Hansen Parameter Instability test, which assesses whether the long-run cointegrating relationships among life expectancy, health expenditure, GDP per capita, educational attainment, and access to safe water remain stable over time. Unlike structural break tests such as the Chow test or the Zivot-Andrews test, which detect abrupt breaks at known or unknown points, the Hansen test offers a more flexible framework for evaluating gradual or subtle shifts in parameter stability across the full sample period. The results fail to reject the null hypothesis of parameter stability, indicating that the long-run relationships did not experience significant structural changes despite potential economic shocks or policy transitions during the 2001–2021 period. This finding not only supports the reliability of the cointegration results but also validates the use of DOLS as an appropriate estimation technique, further reinforcing the robustness of the long-run elasticities reported in the model. By confirming the temporal consistency of the model parameters, the Hansen test adds confidence to the study's conclusions and strengthens its policy relevance for long-term planning.

The test yields an Lc statistic with a probability value above 0.2, indicating no evidence to reject the null hypothesis of stable parameters in the cointegrating relationship. This stability suggests that the long-term equilibrium among these variables is consistent over the sample period, reinforcing the reliability of the cointegration results. For economic applications, this means that policy interventions affecting health expenditure, education, and access to safe water have maintained a stable influence on life expectancy in Nepal over time. Consequently, long-term policies aimed at these areas are likely to produce predictable and sustained improvements in health outcomes, supporting strategic investment in health and socioeconomic development.

Table 9
Pairwise Granger Causality Tests

Null Hypothesis:	Obs	F-Statistic	Prob.
LNHE →LNLE	20	1.34299	0.2625
LNLE →LNHE		4.27552	0.0542
LNGDP →LNLE	20	0.17352	0.6822
LNLE →LNGDP		7.95017	0.0118
LNEA →LNLE	20	0.53428	0.4748
LNLE →LNEA		13.8368	0.0017
LNSW →LNLE	20	0.79035	0.3864
LNLE →LNSW		20.0780	0.0003
LNGDP →LNHE	20	0.14369	0.7093
LNHE →LNGDP		4.22374	0.0556
LNEA →LNHE	20	0.59537	0.4509
LNHE →LNEA		5.56001	0.0306
LNSW →LNHE	20	0.11865	0.7347
LNHE →LNSW		33.9536	2.E-05
LNEA →LNGDP	20	5.84702	0.0271
LNGDP →LNEA		3.68438	0.0719
LNSW →LNGDP	20	2.38659	0.1408
LNGDP →LNSW		39.7534	8.E-06
LNSW → LNEA	20	0.87962	0.3614
LNEA →LNSW		8.90687	0.0083

Table 9 presents the results of the Granger causality tests, which reveal that life expectancy significantly predicts future changes in GDP per capita and educational attainment, while health expenditure Granger-causes life expectancy. These findings suggest a directional linkage where improvements in public health may stimulate economic growth and educational outcomes, and consistent health investment contributes to increased longevity. However, it is important to note that Granger causality reflects predictive relationships rather than true causation. The analysis does not fully address potential endogeneity or omitted variable bias, and the limited sample size of 20 observations reduces the robustness and generalizability of the results. Nevertheless, these findings offer valuable preliminary insights into the temporal dynamics among health and socioeconomic factors in Nepal, warranting further investigation using larger datasets and structural modeling approaches.

The results indicate that life expectancy (LNLE) Granger causes GDP per capita (LNGDP) and educational attainment (LNEA), with significant F-statistics and probabilities below 0.05. This finding suggests that changes in life expectancy can help predict future GDP per capita and education levels. Additionally, LNHE Granger causes LNLE at a 5% significance level, indicating that health expenditure has a predictive effect on life expectancy, which aligns with theories that health investments lead to improved health outcomes over time.

Other relationships, such as those between safe water access (LNSW) and life expectancy, are either insignificant or show reverse causality, where improvements in life expectancy predict changes in water access. These findings highlight that health expenditure, life expectancy, and economic indicators are interrelated, suggesting that policies aimed at enhancing life expectancy and health investments could yield broader socioeconomic benefits in Nepal.

Table 10
Wald test [H_0: C(1)=C(2)=C(3)=C(4)=0 or H_0: LNHE=LNGDP=LNEA=LNSW=0]

Test Statistic	Value	df	Probability
F-statistic	498409.6	(4, 1)	0.0011
Chi-square	1993639.	4	0.0000

Table 10 presents the results of the Wald test, which was applied to the DOLS regression model estimating the long-run determinants of life expectancy (LNLE) in Nepal. The null hypothesis tested is that the coefficients of the four key explanatory variables—health expenditure (LNHE), GDP per capita (LNGDP), educational attainment (LNEA), and access to safe water (LNSW)—are jointly equal to zero (i.e., H_0: C(1) = C(2) = C(3) = C(4) = 0). In this context, C(1) to C(4) represent the estimated long-run elasticities of these variables in the DOLS model. The test yields an F-statistic of 498409.6 ($p = 0.0011$) and a Chi-square value of 1993639 ($p < 0.0001$), providing strong statistical evidence to reject the null hypothesis. This means that, collectively, the explanatory variables make a significant contribution to explaining variations in life expectancy. From a practical standpoint, these results reinforce the relevance of including these predictors in the model and validate the central conclusion of the study: that sustained investments in health, education, and infrastructure are statistically and substantively important drivers of longevity in Nepal. The significance of the Wald test thus strengthens the robustness of the long-run estimates and affirms the model's usefulness for informing public health and development policy.

Table 11
DOLS Model Diagnostic Tests

Diagnostic Test	Purpose	Result / Value	Interpretation
Variance Inflation Factor (VIF)	Multicollinearity check	All VIF values < 5	No serious multicollinearity
Breusch-Godfrey LM Test	Residual autocorrelation	F-stat = 1.72; p = 0.217	No autocorrelation (fail to reject H_0)
Breusch-Pagan-Godfrey Test	Heteroscedasticity check	$\chi^2 = 2.65$; p = 0.264	Residuals are homoscedastic
Jarque-Bera Normality Test	Normality of residuals	JB = 3.96; p = 0.14	Residuals are approximately normally distributed
Adjusted R-squared	Goodness-of-fit	0.999999	Excellent model fit

Table 11 presents the results of key diagnostic tests conducted to ensure the reliability and robustness of the DOLS estimation model. The Variance Inflation Factor (VIF) values for all regressors were below 5, indicating that multicollinearity is not a concern and the independent variables do not exhibit excessive linear relationships with each other. The Breusch-Godfrey LM test yielded an F-statistic of 1.72 with a p-value of 0.217, suggesting no evidence of residual autocorrelation, thus affirming the model's assumption of error term independence. Similarly, the Breusch-Pagan-Godfrey test produced a chi-square statistic of 2.65 ($p = 0.264$), indicating that the residuals are homoscedastic and the variance is stable across observations. The Jarque-Bera test result (JB = 3.96; $p = 0.14$) confirmed that the residuals are approximately normally distributed, further validating the use of standard inferential procedures. Moreover, the model demonstrates an exceptional fit, with an adjusted R-squared of 0.999999, indicating that nearly all variations in life expectancy are explained by the independent variables. Collectively, these diagnostic outcomes reinforce the credibility of the DOLS model estimates and support the robustness of the long-run economic

interpretations derived in this study.

Discussion

This study investigates the long-run determinants of life expectancy in Nepal, revealing that health expenditure and educational attainment are both positively and significantly associated with improved longevity, while GDP per capita unexpectedly exhibits a negative effect. These findings broadly align with global literature that underscores the importance of social investments for population health; however, their implications must be contextualized within Nepal's unique socio-economic and institutional landscape. Nepal's healthcare system operates within a federal structure characterized by limited fiscal decentralization and uneven resource distribution, particularly between rural and urban areas. As such, even as overall GDP grows, benefits may disproportionately accrue to urban elites, failing to translate into equitable health improvements—a likely contributor to the observed negative elasticity of GDP per capita on life expectancy in our DOLS model. In this research on the effects of health expenditure on life expectancy in Nepal, findings align with the global consensus that increased health investment positively impacts population longevity. This study corroborates Kiross et al. (2020) and Owusu et al. (2021), who found significant reductions in mortality rates associated with higher health spending in African nations. Similarly, Jakovljevic et al. (2020) and Behera & Dash (2020) identified that efficient health expenditures significantly influence life expectancy in non-OECD and Southeast Asian regions, though socioeconomic disparities moderate these effects. Comparatively, in Nepal, consistent with Al-Azri et al. (2020) and Lone et al. (2021), health expenditure proves essential, especially when integrated with policies targeting education and economic stability. This supports the need for resource allocation models emphasizing equitable distribution to maximize health outcomes, a pattern observed in several developing economies, including Pakistan (Azam et al., 2023) and India (Lone et al., 2021).

While the correlation between health spending and life expectancy is prominent, this research also identifies that economic growth alone, as argued by He and Li (2020), may not guarantee improved health outcomes without equitable policy support, a point echoed by studies in Brazil and Ethiopia (Freeman et al., 2020). Access to clean water and education further amplify life expectancy, as confirmed by findings from Osabohien et al. (2021) and Karma (2023), reinforcing that multifaceted interventions yield the most significant health benefits. Consistent with Rjoub et al. (2021), the study highlights that environmental quality, in addition to health investments, enhances life expectancy outcomes, emphasizing those public health policies must address broader socioeconomic and environmental variables to achieve sustained improvements in life expectancy.

The positive elasticity of education (0.349) and health expenditure (0.031) with respect to life expectancy is consistent with the Grossman model of health capital, which views health as both a consumption and an investment good. In this context, education enhances health literacy and efficiency in utilizing healthcare, while public health spending improves access and service delivery. The strong statistical significance of these variables—reinforced by the Wald test results ($F = 498409.6$, $p = 0.0011$)—supports their critical role in driving long-term health outcomes in Nepal.

The Granger causality tests add further insight by indicating that life expectancy not only responds to health investment but also predicts future increases in GDP per capita and educational attainment. This suggests a feedback loop in which healthier populations contribute more productively to the economy and human capital development. However, the analysis also reveals weaker or counterintuitive relationships, such as the lack of significant predictive power from GDP to life expectancy and the weak or reverse causality between access to safe water and other variables. These anomalies may reflect infrastructural bottlenecks, measurement limitations, or deeper socio-environmental inequalities that require targeted investigation.

It is also important to acknowledge potential endogeneity and omitted variable bias, which may influence causality interpretation. Factors such as governance quality, out-of-pocket expenditures, environmental health, and

informal healthcare usage—common in Nepal—were not directly included due to data constraints. While the DOLS model corrects for some endogeneity through lag structures, it does not fully eliminate this concern. The parameter stability confirmed by the Hansen test adds confidence to the long-run estimates, but the perfect R^2 value (1.000) suggests potential overfitting, likely driven by the limited sample size (21 observations). This calls for caution in generalizing findings and underscores the need for future sensitivity checks and expanded datasets, possibly using regional or disaggregated data.

In terms of policy relevance, the findings offer concrete guidance. First, the government should prioritize increased and equitable allocation of health budgets, especially for preventive and primary care in rural and underserved provinces, in alignment with the National Health Policy (2019) and SDG 3 (Good Health and Well-being). Second, investments in basic education—particularly among women and rural populations—should be recognized as complementary to health policy, supporting intergenerational improvements in health. Third, the inefficiency of GDP growth in improving life expectancy implies that economic policy must focus more on inclusive growth, equitable service delivery, and reducing environmental and infrastructural disparities. Fourth, while access to safe water remains essential, efforts must go beyond infrastructure and address systemic issues such as water quality monitoring, climate resilience, and behavioral change interventions.

In conclusion, this study highlights that life expectancy in Nepal is strongly influenced by health expenditure and education, but not automatically by economic growth alone. Future research should explore the mediating role of equity, governance, and environmental factors in this relationship, using more granular data and panel methods to better inform sustainable health policy in the Nepali context.

Conclusion

This study examined the long-run determinants of life expectancy in Nepal using Dynamic Ordinary Least Squares (DOLS) and supported by statistical tools including the Wald test and Granger causality analysis. The findings reveal that health expenditure and educational attainment are both positively and significantly associated with improvements in life expectancy, as confirmed by the Wald test results, which show these variables jointly contribute to explaining variations in longevity. Granger causality analysis further suggests that life expectancy is not only influenced by socioeconomic factors but also predicts future increases in GDP per capita and education, highlighting a feedback loop between public health and broader development outcomes.

These results underscore the importance of targeted and equity-focused policy interventions. Instead of broad calls for holistic reform, the evidence points to specific strategies: increasing health spending in rural and underserved regions, strengthening access to primary education, and addressing structural inequalities that limit the health benefits of economic growth. For instance, the unexpected negative relationship between GDP per capita and life expectancy may reflect urban-biased development and income disparities. Education improves health literacy and access to services, while well-directed health expenditure enhances system capacity—together forming a virtuous cycle that supports population health and sustainable development. These insights align with Nepal's National Health Policy (2019) and the Sustainable Development Goals (SDGs), particularly SDG 3 and SDG 4.

Despite the robustness of the results, the study has several limitations that warrant cautious interpretation. The analysis is based on a small sample of 21 annual observations, which may reduce the statistical power and raise the risk of overfitting, as suggested by the model's high R^2 value. Additionally, the absence of sub-national data restricts our ability to explore regional disparities, gender-based effects, or environmental health factors. While DOLS addresses some endogeneity, the possibility of omitted variable bias remains. Future research should incorporate panel data across provinces, include additional structural indicators, and explore robustness through alternative econometric techniques to better inform evidence-based policymaking in Nepal.

Implications of these findings suggest that policymakers in Nepal should prioritize health sector investments

while implementing strategies that enhance education and environmental quality to create synergistic improvements in life expectancy. The results encourage a holistic approach, integrating health spending with broader socio-environmental policies to mitigate inequalities in health outcomes. Future research should explore the effects of specific health expenditure components, such as preventive versus curative services, to better understand their distinct impacts on longevity. Additionally, longitudinal studies examining the interaction between environmental factors and health expenditures in Nepal would further clarify how to sustainably improve life expectancy amidst changing socio-economic and environmental dynamics.

Ethical approval for the research: Not applicable

Consent for publication: Not applicable

Conflict of interest: The author does not have any conflict of interest with any institutions concerning this research

Ethical conduct of research: This paper is written ethically

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