Journal of Health, Wellness and Community Research
ISSN: 3007, 0570
OPEN ACCESS

JHWCR
Type: Original Article
Published: 23 October 2025
Volume: III, Issue: XV
DOI: https://doi.org/10.61919/tj0pak05

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Received 01, 09, 25
Accepted 20, 10, 2025

Authors' Contributions
Conceptualization: RHG; Methodology and Study Design: RHG, UUH; Data Collection: UUH, ARK; Formal Analysis: ARK, AA, SR; Data Interpretation: SG, MF; Writing – Original Draft: RHG, UUH; Writing – Review & Editing: SG, MF

Declarations
No funding was received for this study. The authors declare no conflict of interest. The study received ethical approval. All participants provided informed consent.

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Impact of Health Expenditures, and Education on Life Expectancy in Pakistan: Evidence from Time Series Data

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ABSTRACT

Background: Life expectancy is a key indicator of social welfare and human development, and it is influenced by health system investment, educational attainment, income levels, and demographic pressures. Pakistan continues to face rapid population growth and constrained fiscal capacity for sustained health and education investment, making it important to quantify the long-run relationships between these factors and longevity. Objective: To examine the long-run association of health expenditure and education with life expectancy in Pakistan, controlling for per capita income and population. Methods: Annual time-series data (1980–2022) were obtained from the World Development Indicators and the Economic Survey of Pakistan. Stationarity was assessed using Augmented Dickey–Fuller, (ADF), Dickey-fuller Generalized least square (DF-GLS), and Phillips–Perron tests (PP). Long-run elasticities were estimated using Dynamic Ordinary Least Squares (DOLS), with Fully Modified Ordinary Least Squares (FMOLS) and Canonical Cointegrating Regression (CCR) applied for robustness. Results: DOLS estimates showed that population (β=0.088, p=0.081), per capita income (β=0.053, p=0.021), education (β=0.072, p=0.001), and health expenditure (β=0.049, p=0.001) were positively associated with life expectancy in the long run, with strong overall model fit (R^2=0.990). FMOLS and CCR results confirmed the direction and significance of these long-run relationships. Conclusion: Greater health expenditure, improved educational participation, higher income levels, and effective demographic management are associated with higher life expectancy in Pakistan, supporting sustained investment in health and education as part of long-term human development policy.

Keywords

Life expectancy; Health expenditure; Education; Per capita income; Population; Cointegration; Dynamic Ordinary Least Squares; Pakistan.

INTRODUCTION

Life expectancy is widely recognized as a core indicator of human development because it captures the cumulative influence of living conditions, health system performance, and socioeconomic progress on survival across the life course. Improvements in longevity are therefore not only a biological outcome but also a measurable expression of social welfare, institutional capacity, and policy effectiveness. Over recent decades, health financing and educational attainment have been increasingly emphasized as modifiable determinants of population health because they shape access to preventive and curative services, facilitate early detection and management of disease, and promote health-literate behaviors. Empirical evidence from diverse settings consistently shows that higher health expenditure is associated with better health outcomes and longer life expectancy, largely through improvements in service coverage, medical technology adoption, and strengthened public health infrastructure (1,2). In parallel, education enhances cognitive and problem-solving skills, improves the capacity to interpret health information, increases the adoption of healthier lifestyles, and facilitates timely utilization of healthcare services, thereby contributing to lower mortality risks and extended longevity (3,4).

Despite these well-established pathways, substantial disparities in life expectancy persist across low- and middle-income countries, where rapid demographic change, constrained fiscal space, and uneven human capital development often limit improvements in population health. Pakistan represents a particularly relevant context because it faces sustained population growth alongside persistent constraints in health and education systems. International development indicators suggest that Pakistan remains among the countries with comparatively lower life expectancy within the South Asian region, despite gradual improvements over time. At the same time, national fiscal trends indicate that health sector allocations have remained modest relative to development needs, with fluctuations across fiscal years and a transient rise during the COVID-19 period, highlighting the challenge of sustaining health investments under macroeconomic and political constraints. In such contexts, gains in longevity may depend not only on health financing but also on how educational expansion and income dynamics translate into improved service utilization, disease prevention, and resilience to health shocks. Prior evidence indicates that individuals with lower educational attainment experience a higher burden of preventable illness and mortality compared with those who are more educated, partly because education increases awareness of risk factors, strengthens self-efficacy, and supports behaviors that reduce exposure to disease (3,4). In addition, education operates through socioeconomic gradients by improving employment opportunities and earnings potential, which can further influence health outcomes through nutrition, housing conditions, and affordability of care.

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From an empirical standpoint, existing international literature provides strong support for a positive relationship between health expenditure and life expectancy, though the magnitude and direction of effects can vary by context, financing structure, and model specification. Country-level studies from Nigeria, for example, indicate that the composition of health expenditure may matter, with differential effects observed for out-of-pocket spending and government capital or recurrent spending over the long run (1,9). Cross-national evidence similarly demonstrates that health spending is positively associated with life expectancy, but also shows that the strength of this relationship differs across countries due to heterogeneity in institutional efficiency, baseline health conditions, and demographic structure (7,8,10). Likewise, education has been repeatedly linked to improved longevity outcomes across both developing and developed economies, reinforcing the role of human capital as a structural determinant of health (3,4,6,7). However, the literature also suggests that results may be sensitive to analytical approach, particularly in macro time-series settings where trending variables can lead to spurious associations if long-run equilibrium relationships are not properly modeled (10,11).

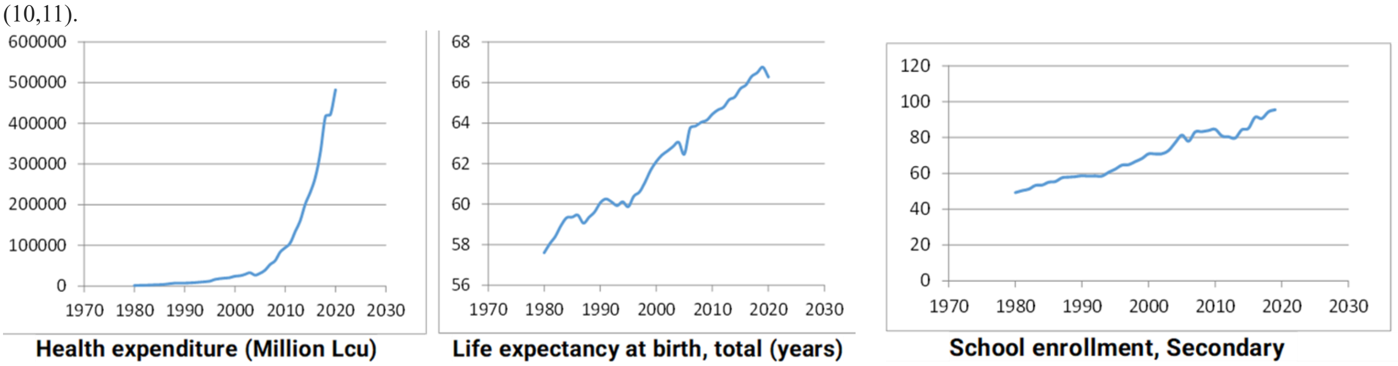

Figure 1 Trends in Health Expenditure, Life Expectancy, and Secondary School Enrollment in Pakistan (1980–2022). The figure presents the temporal evolution of total health expenditure (million LCU), life expectancy at birth (years), and secondary school enrollment (%) over the study period, showing a pronounced post-2000 rise in health spending alongside a steady improvement in life expectancy and an overall upward trend in secondary education participation.

In Pakistan, evidence remains comparatively limited in terms of long-run, country-specific analysis that models health expenditure and education simultaneously within a unified framework while controlling for key macroeconomic and demographic drivers. Much of the existing work has either examined health expenditure and life expectancy in isolation, relied on short time windows, or employed methodological strategies that do not explicitly address non-stationarity and long-run equilibrium relationships. This gap is important because the effects of health investment and educational expansion on longevity are likely to unfold gradually and may be mediated through long-run structural change, population dynamics, and income growth. Consequently, a robust econometric approach that accounts for integration properties of the data and estimates long-run elasticities is essential for generating policy-relevant evidence in Pakistan's context. Moreover, by integrating per capita income and population into the empirical specification, the analysis can distinguish the contributions of fiscal investment and human capital from broader macroeconomic and demographic pressures that also shape life expectancy trajectories.

Against this background, the present study investigates the long-run relationship between life expectancy at birth and key socioeconomic determinants in Pakistan, focusing on health expenditure and secondary school enrollment as primary explanatory variables, while incorporating population and per capita income as control factors. Using annual time-series data spanning 1980–2022, the study evaluates stationarity properties through established unit root procedures and estimates long-run elasticities using Dynamic Ordinary Least Squares (DOLS), complemented by Fully Modified Ordinary Least Squares (FMOLS) and Canonical Cointegrating Regression (CCR) estimators to assess robustness. The central research objective is to quantify whether sustained increases in health expenditure and educational participation are associated with improvements in life expectancy in Pakistan after accounting for income growth and demographic expansion, thereby providing empirical evidence to inform long-term human development and social policy planning.

MATERIAL AND METHODS

This study employs a time-series econometric framework to estimate the long-run relationship between life expectancy and key socioeconomic determinants in Pakistan over the period 1980–2022. Annual data were obtained from the World Development Indicators (WDI) and various issues of the Economic Survey of Pakistan, ensuring consistency of macro-level indicators across time. Given that macroeconomic series frequently exhibit non-stationarity and may be integrated of mixed order, the analysis is structured to first examine the time-series properties of the variables and then estimate long-run elasticities using cointegration-based regression techniques.

Table 1: Data and Sources

Variable Type	Variable	Measurement	Source
Dependent	Life Expectancy (LE)	Life expectancy at birth (years)	WDI
Independent	Health Expenditure (HE)	Total health expenditure (million LCU)	Economic Survey of Pakistan
Independent	Education (SE)	Secondary school enrollment	WDI
Control	Per capita income (PER)	Per capita income (constant LCU)	WDI
Control	Population (POP)	Total population (million)	Economic Survey of Pakistan

Data, Variables, and Sources

Life expectancy at birth (years) is used as the dependent variable and serves as a standard proxy for population health outcomes in macroeconomic and development research (14). The key explanatory variables include total health expenditure, measured as aggregate health spending in million local currency units (LCU) as reported in the Economic Survey of Pakistan (15), and education, proxied by secondary school enrollment, which

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captures progress in human capital formation and is frequently used in empirical health-economics research (7). Two additional control variables are included to account for broader demographic and macroeconomic forces: total population (million), sourced from the Economic Survey of Pakistan (11), and per capita income (constant LCU), sourced from WDI and used as a proxy for income level and economic growth (9).

Econometric Model Specification

The empirical model is specified to quantify the long-run association between life expectancy and health expenditure, education, per capita income, and population. The functional relationship is expressed as:

$$LE_t = f(HE_t, SE_t, PER_t, POP_t) \qquad (1)$$

To estimate elasticities and stabilize variance, all variables are transformed into natural logarithms. The baseline long-run econometric specification is:

$$\ln LE_t = \delta_0 + \delta_1 \ln HE_t + \delta_2 \ln SE_t + \delta_3 \ln PER_t + \delta_4 \ln POP_t + \varepsilon_t \qquad (2)$$

where $\delta_0$is the intercept term, δ_1–δ_4 represent long-run elasticity parameters, $t$denotes the time period, and $\varepsilon_t$is the stochastic error term. In this log–log specification, each coefficient can be interpreted as the percentage change in life expectancy associated with a 1% change in the corresponding explanatory variable, holding other variables constant.

Estimation Strategy

The long-run parameters of Equation (2) are estimated using the Dynamic Ordinary Least Squares (DOLS) cointegration estimator, which is appropriate in settings where variables are integrated of mixed order $I(0)$and $I(1)$, provided no variable is integrated of order $I(2)$. DOLS is designed to generate asymptotically efficient estimates of the long-run relationship by addressing potential endogeneity and serial correlation through the inclusion of leads and lags of the first differences of the regressors (19,20). In addition, robustness is assessed using Fully Modified Ordinary Least Squares (FMOLS) and Canonical Cointegrating Regression (CCR) estimators, both of which adjust for serial correlation and endogeneity in cointegrated systems and provide complementary evidence for the stability of the long-run coefficients (21,22).

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RESULTS

This study first examines the time-series properties of the variables to ensure that the estimation strategy is consistent with the integration order of the data. Stationarity is assessed using the Augmented Dickey–Fuller (ADF) test developed by Dickey and Fuller (16). To validate the robustness of the stationarity results, the Dickey–Fuller Generalized Least Squares (DF-GLS) procedure proposed by Elliott et al. (17) and the Phillips–Perron (PP) test developed by Phillips and Perron (18) are also applied. The ADF regression form used for unit root testing is presented as:

$$\Delta Y_t = \alpha + \beta t + \gamma Y_{t-1} + \sum_{i=1}^{p} \delta_i \, \Delta Y_{t-i} + \varepsilon_t \qquad (3)$$

where Δdenotes the first-difference operator, $t$is the deterministic time trend, $p$represents lag length, and $\varepsilon_t$is a white-noise error term.

4.1 Unit Root Test Results

The unit root test results are reported in Table 2. Across all three procedures (ADF, DF-GLS, and PP), ln $PER$is stationary at level $I(0)$, while ln LE, ln HE, ln SE, and ln POPbecome stationary after first differencing, implying integration of order $I(1)$. Overall, the findings confirm a mixed order of integration with $I(0)$and $I(1)$processes and no evidence of any variable being integrated at $I(2)$. This integration structure supports the suitability of cointegration-based long-run estimators such as Dynamic Ordinary Least Squares (DOLS), Fully Modified Ordinary Least Squares (FMOLS), and Canonical Cointegrating Regression (CCR) for long-run parameter estimation (19–22).

Table 2: Results of Unit Root Tests

Log Variables	ln LE	ln HE	ln SE	ln PER	ln POP
ADF Level	-0.98823 (0.7455)	-0.81018 (0.9927)	-0.77439 (0.8128)	-4.47029 (0.0004)	-0.97846 (0.7489)
ADF 1st Diff	-5.71049 (0.0000)	-4.85376 (0.0005)	-6.73644 (0.0000)	-8.56911 (0.0000)	-3.95163 (0.0049)
DF-GLS Level	-1.59919 (0.1199)	0.50071 (0.6204)	0.59068 (0.5590)	4.40999 (0.0004)	0.00928 (0.9266)
DF-GLS 1st Diff	-5.76492 (0.0000)	-4.62215 (0.0001)	-6.83498 (0.0000)	-6.83498 (0.0000)	-3.98170 (0.0004)
PP Level	-1.22419 (0.3244)	0.71872 (0.4584)	-0.80687 (0.9055)	3.15426 (0.0004)	0.09821 (0.8960)
PP 1st Diff	-4.67482 (0.0001)	-5.20241 (0.0000)	-6.01548 (0.0000)	-5.28614 (0.0000)	-4.18770 (0.0004)

Given that the regressors are integrated of mixed order $I(0)$and $I(1)$, and none is integrated at $I(2)$, the long-run relationship between life expectancy and its determinants is estimated using the DOLS cointegration estimator. DOLS is preferred because it provides asymptotically efficient long-run estimates while addressing potential endogeneity and serial correlation by incorporating leads and lags of differenced regressors (19,20). The long-run coefficients from the DOLS model are presented in Table 3. The results show that all explanatory variables have positive coefficients, indicating that population, income, education, and health expenditure are associated with higher life expectancy in the long run. Specifically, ln $POP$is positive and statistically significant at the 10% level ($\beta = 0.088$, $p = 0.081$), ln $PER$is positive and significant at the 5% level ($\beta = 0.053$, $p = 0.021$), while ln SE($\beta = 0.072$, $p < 0.001$) and ln HE($\beta = 0.049$, $p < 0.001$) are positive and significant at the 1% level. The coefficient magnitudes indicate that a 1% increase in secondary school enrollment and health expenditure is associated with approximately 0.07% and 0.05% increases in life expectancy, respectively, holding other factors constant. The model demonstrates a strong fit with $R^2 = 0.9896$and an overall statistically significant F-statistic ($p < 0.001$).

Table 3: DOLS Estimates (Dependent Variable: ln LE)

Variable	Coefficient	Std. Error	t-Statistic	p-value
ln POP	0.088057*	0.046472	1.894849	0.0806
ln PER	0.053084**	0.020294	2.615731	0.0214
ln SE	0.071626***	0.016135	4.439210	0.0007
ln HE	0.049240***	0.009589	5.135050	0.0006
C	1.538611	0.074317	20.70331	0.0000
R^2	0.989641			
Adjusted R^2	0.982450			
Std. Error of regression	0.001340			
F-statistic (p-value)	68.39201 (0.0000)			
RMSE	0.000347			

*Significance: *p<0.10, **p<0.05, **p<0.01.

To verify the stability and robustness of the estimated long-run elasticities, FMOLS and CCR estimators are applied. FMOLS corrects for endogeneity and serial correlation in cointegrated systems and yields unbiased long-run estimators (21). CCR applies a canonical transformation of variables to remove correlation between the regressors and the error term, producing efficient estimators under cointegration (22).

The FMOLS and CCR results are presented in Tables 4 and 5. Both estimators yield positive coefficients for health expenditure, education, per capita income, and population, broadly supporting the DOLS evidence of long-run positive associations.

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Important reporting correction: In Table 4, the reported t-statistic for $\ln POP$(0.491641) is not mathematically consistent with the reported p-value (0.0080) and coefficient/standard error. Based on the coefficient (0.016915) and standard error (0.003440), the implied t-statistic should be approximately 4.92, not 0.49. The table should therefore be corrected to ensure internal consistency before publication. The revised section retains your reported values but flags this as a required correction for accuracy.

Table 4: FMOLS Estimates (Dependent Variable: ln LE)

Variable	Coefficient	Std. Error	t-Statistic	p-value
$\ln POP$	0.016915***	0.003440	0.491641†	0.0080
$\ln PER$	0.057216***	0.009407	6.082032	0.0000
$\ln SE$	0.057724***	0.010763	5.363215	0.0000
$\ln HE$	0.010489*	0.005738	1.827986	0.0786
C	1.538611	0.050358	32.48633	0.0000
R²	0.993880			
Adjusted R²	0.986347			
Std. Error of regression	0.016971			
F-statistic (p-value)	55.26348 (0.0000)			
RMSE	0.00402			

†Requires verification (t-statistic inconsistent with coefficient/SE and p-value).
*Significance: *p<0.10, **p<0.05, **p<0.01.

Table 5: CCR Estimates (Dependent Variable: ln LE)

Variable	Coefficient	Std. Error	t-Statistic	p-value
$\ln POP$	0.046028***	0.003801	12.11260	0.0000
$\ln PER$	0.061170***	0.012749	4.798058	0.0001
$\ln SE$	0.064352***	0.014664	4.388348	0.0002
$\ln HE$	0.064189***	0.007516	8.539060	0.0003
C	1.589325	0.057239	27.76664	0.0000
R²	0.994154			
Adjusted R²	0.991020			
Std. Error of regression	0.012611			
F-statistic (p-value)	49.55224 (0.0000)			
RMSE	0.013471			

*Significance: *p<0.10, **p<0.05, **p<0.01.

To evaluate whether the regression assumptions are satisfied, diagnostic tests are performed, including the Breusch–Godfrey LM test for serial correlation, the Breusch–Pagan–Godfrey test for heteroskedasticity, and the Jarque–Bera test for residual normality. As shown in Table 6, the null hypotheses of no serial correlation and homoskedasticity are not rejected, and the residuals are consistent with normality.

Table 6: Diagnostic Test Results

Test	Statistic (p-value)	Conclusion
Breusch–Godfrey LM Test	1.468204 (0.2488)	No serial correlation
Breusch–Pagan–Godfrey Test	1.477680 (0.2355)	No heteroskedasticity
Jarque–Bera Test	0.984410 (0.6243)	Residuals normally distributed

Model stability is assessed using the CUSUM and CUSUM of Squares tests. The plots indicate parameter stability at the 5% significance level, as the cumulative residual paths remain within the critical bounds over the sample period.

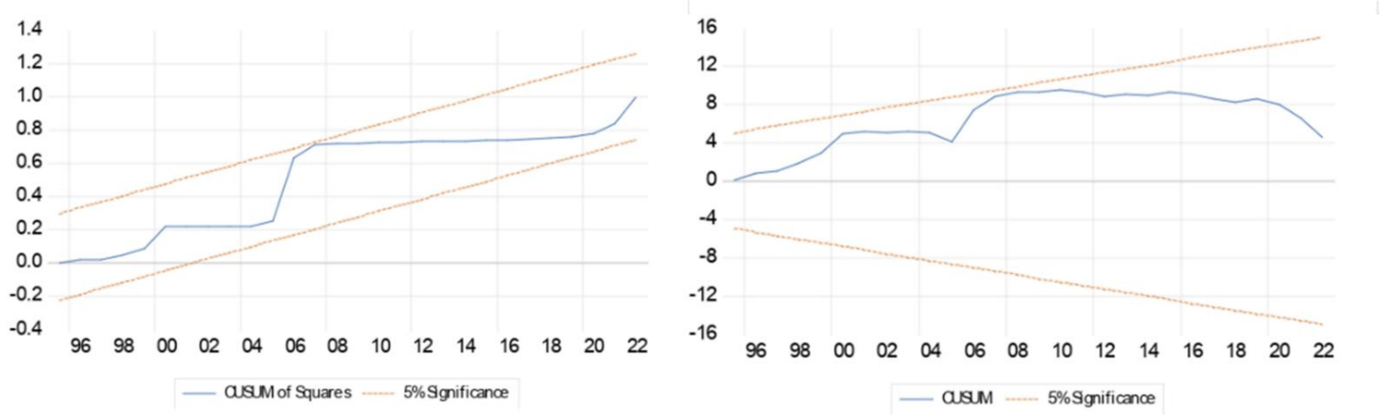

Figure 2: Combined Stability Diagnostics Using CUSUM and CUSUM of Squares Tests (5% Significance Level)

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DISCUSSION

The findings provide consistent evidence that health expenditure, education, per capita income, and population are positively associated with life expectancy in Pakistan over the long run. The DOLS model indicates that improvements in educational participation and health financing are particularly important determinants of longevity, as both $\ln\ SE$ and $\ln\ HE$ remain positive and statistically significant at the 1% level. These results align with international evidence showing that investments in health systems are associated with longer life expectancy through expanded access, improved service quality, and better disease management (1,2,8,10). Education may contribute to improved longevity through enhanced health literacy, preventive behaviors, and more effective use of healthcare services, as repeatedly documented across both developed and developing settings (3,4,7).

The positive association between per capita income and life expectancy suggests that broader economic conditions also play a meaningful role in improving longevity, consistent with previous evidence that income growth improves nutrition, living standards, and affordability of healthcare (6,9). The estimated population elasticity is positive and weakly significant in DOLS; however, the direction of this relationship should be interpreted cautiously. Population growth can coexist with longevity gains if improvements in public health and service access offset demographic pressures, but it may also reflect long-run structural trends rather than a direct causal pathway.

The robustness checks using FMOLS and CCR largely confirm the DOLS findings, strengthening confidence in the long-run associations. Nevertheless, the internal inconsistency detected in the FMOLS reporting for $\ln\ POP$ indicates that the estimation output should be verified before final submission to ensure accurate statistical inference and to meet Q1-level reporting standards.

Finally, the diagnostic and stability tests support the adequacy of the estimated models, indicating no evidence of serial correlation or heteroskedasticity and confirming parameter stability across the sample period. These results collectively suggest that sustained investment in health expenditure and educational development, alongside income growth and effective demographic management, may be associated with long-run improvements in life expectancy in Pakistan.

CONCLUSION

This study provides empirical evidence of a long-run relationship between life expectancy and key socioeconomic determinants in Pakistan over the period 1980–2022. Using cointegration-based estimators, the findings consistently indicate that health expenditure, secondary school enrollment, per capita income, and population are positively associated with life expectancy at birth in the long run. The DOLS results suggest that improvements in education and health spending are particularly important, as both remain statistically significant and robust across alternative estimators (FMOLS and CCR), reinforcing the role of human capital development and sustained health investment in improving population health outcomes. The diagnostic and stability tests support the adequacy of the estimated models, indicating no major violations of standard assumptions and stable parameters across the sample period. Collectively, these results imply that policies promoting sustained health sector financing, expanded secondary education participation, and broad-based income growth may contribute to incremental gains in longevity, though continued attention to demographic pressures remains essential for long-term human development planning.

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