

Healthcare Spending and Population Health in Low- and Middle-Income Countries: A Longitudinal Panel Analysis, 2000-2023

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Abstract

Debate about health financing in low- and middle-income countries often assumes that additional spending improves population health but yields smaller gains at higher expenditure levels. This study examined the longitudinal and nonlinear associations between current health expenditure per capita and life expectancy, infant mortality, and under-five mortality. An ecological country-year panel was assembled from World Health Organization-derived and World Bank indicators for 2000-2023. Countries classified by the World Bank as low, lower-middle, or upper-middle income at data retrieval were eligible. The primary specification used country and year fixed effects, adjustment for gross domestic product per capita and urbanization, and country-clustered robust standard errors. Nonlinearity was evaluated with quadratic terms and a four-knot restricted cubic spline. The life-expectancy model included 2,916 observations from 124 countries. Although pooled and country-only fixed-effects models showed positive associations, the two-way fixed-effects estimate for log health expenditure was -0.30 years (95% confidence interval [CI], -1.22 to 0.63; $p=.526$). Log-spending elasticities were -0.048 for infant mortality (95% CI, -0.116 to 0.020; $p=.167$) and -0.036 for under-five mortality (95% CI, -0.102 to 0.029; $p=.270$). Flexible models identified nonlinearity (joint $p<.001$), but the adjusted pattern was not the hypothesized monotonic improvement with diminishing gains. Income-group interaction tests were significant ($p<.001$), with a positive association confined to low-income countries and inverse estimates in higher-income groups. Findings were stable across covariate, lagged-exposure, pre-pandemic, and balanced-panel sensitivity analyses. The results do not establish that spending is ineffective; rather, aggregate expenditure alone was not consistently associated with within-country health improvement after common time trends were removed. Financing decisions should consider expenditure composition, implementation quality, and health-system efficiency.

Keywords: Health expenditure; health financing; population health; low- and middle-income countries; panel data; life expectancy

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Introduction

Current health expenditure captures resources consumed for health goods and services during a year under the System of Health Accounts framework.¹ Internationally comparable expenditure data help governments monitor how health systems mobilize and use resources, but expenditure is an input rather than a health outcome.² Health-production theory treats medical care as one contributor to health alongside income, education, living conditions, behavior, and population structure.³ Consequently, equal additions to health budgets need not generate equal population-health gains.

The expectation of diminishing marginal health returns is intuitively plausible. At very low spending levels, additional resources may finance vaccinations, essential medicines, primary care, and basic service capacity. At higher levels, remaining health problems may be more complex and marginal interventions more costly. The well-known nonlinear relation between income and longevity also illustrates why associations observed across countries may flatten as resource levels rise.⁴ Yet public services and

household income jointly shape health, making simple spending-outcome correlations difficult to interpret.⁵

Empirical evidence is mixed. Some cross-country studies found weak or context-dependent relationships after adjustment for income and other determinants,⁶ whereas other work linked greater government or total health spending to lower child mortality or improved longevity.⁷⁻¹⁰ Panel and instrumental-variable studies have emphasized that country heterogeneity, health-service coverage, governance, and reverse causality can materially change estimates.^{11,12} A meta-regression likewise found that effect sizes vary by outcome, specification, and study characteristics.¹³ Recent sub-Saharan African evidence remains heterogeneous across estimators and spending measures.¹⁴ Much of this literature estimates a single linear or log-linear coefficient, while fewer multicountry LMIC analyses explicitly trace marginal associations across the spending distribution using contemporary data and multiple outcomes.

This study asked whether additional health expenditure was associated with progressively smaller improvements in population health across LMICs. The study hypothesized that higher per-capita expenditure would be associated with longer life expectancy and lower infant and under-five mortality, with weaker incremental improvements at higher expenditure. It also tested whether associations differed across World Bank income groups. Because the design was observational and ecological, all estimates were interpreted as country-level associations rather than causal effects.

Methods

Study design and population

A longitudinal ecological panel design was used, with the country-year as the unit of analysis. The study period was 2000-2023, the longest common interval supported by the health-expenditure series at retrieval. Eligible economies were classified by the World Bank application programming interface as low, lower-middle, or upper-middle income.^{15,16} A fixed retrieval-date classification was used to define a contemporary LMIC policy population and prevent countries from entering or leaving the sample annually because of short-term classification changes. Aggregates and high-income economies were excluded. The resulting panel was unbalanced; observations were not interpolated.

Data sources and variables

Data were downloaded programmatically from World Development Indicators.¹⁵ The primary exposure was current health expenditure per capita in purchasing-power-parity (PPP) international dollars

Table 1. Variables, sources, transformations, and analytical roles

Variable	World Bank code	Unit	Transform	Role
Current health expenditure per capita	SH.XPD.CHEX.PP.CD	PPP current international \$	Natural log	Primary exposure
Life expectancy at birth	SP.DYN.LE00.IN	Years	None	Primary outcome
Infant mortality	SP.DYN.IMR.T.IN	Deaths/1,000	Natural log	Secondary

GDP, gross domestic product; PPP, purchasing power parity. Health-expenditure data originate from WHO and are republished in World Development Indicators.

Statistical analysis

(SH.XPD.CHEX.PP.CD), a WHO Global Health Expenditure Database series republished by the World Bank.² Its natural logarithm was used because the distribution was strongly right-skewed. Current health expenditure as a percentage of gross domestic product (GDP) was examined in sensitivity analysis.

The primary outcome was life expectancy at birth in years. Secondary outcomes were infant and under-five deaths per 1,000 live births; both mortality outcomes were log transformed. The prespecified primary covariates were log GDP per capita in constant 2021 PPP dollars and urban population percentage. GDP represented broader material resources that influence both fiscal capacity and health, and urbanization represented differences in service access and population organization. Basic sanitation coverage was added in sensitivity analysis because it may confound health outcomes but had slightly lower completeness. Physician density and education were not included in the primary model because missingness would substantially change the estimand and because health-system capacity may partly mediate expenditure.

Data management

Indicator files were merged by ISO3 economy code and year. Aggregates were removed, duplicates were checked, units were verified, and impossible ranges were screened. The data dictionary, raw files, inclusion table, code, and numerical outputs accompany the reproducibility package. Missingness was described by variable, year, and income group. Primary analyses used complete observations for each model without mean substitution or imputation.

ity		live births		outcome
Under-five mortality	SH.DYN.MORT	Deaths/1,000 live births	Natural log	Secondary outcome
GDP per capita	NY.GDP.PCAP.KD	Constant 2021 PPP \$	Natural log	Primary covariate
Urban population	SP.URB.TOTL.IN.ZS	% of population	None	Primary covariate
Basic sanitation	SH.STA.BAS.S.ZS	% of population	None	Sensitivity covariate

Distributions were summarized using means, standard deviations, medians, interquartile ranges, and ranges. Sequential life-expectancy models included: bivariate ordinary least squares; pooled adjusted ordinary least squares; country fixed effects;

and country plus year fixed effects. The primary two-way model was

$$Y_{it} = \beta_1 \ln(\text{health expenditure}_{it}) + \beta_2 X_{it} + \text{country}_i + \text{year}_t + \text{error}_{it}$$

Country effects controlled stable observed and unobserved differences; year effects controlled shocks and secular changes shared across countries.¹⁷ Standard errors were clustered by country to allow heteroskedasticity and arbitrary within-country dependence.¹⁸ Exact two-sided p-values were reported, with $p < .05$ used as a conventional precision threshold rather than a decision rule.

Nonlinearity was assessed using expenditure in PPP \$1,000 units plus its squared term and a restricted cubic spline in log expenditure with knots at the 5th, 35th, 65th, and 95th percentiles.¹⁹ Marginal changes were calculated from the spline at spending quartiles with delta-method 95% CIs. Income-group heterogeneity was tested using interactions between log spending and fixed retrieval-date income group; the two interaction terms were tested jointly. Core models were repeated for log infant and under-five mortality.

Sensitivity analyses added sanitation, removed GDP, substituted expenditure as a percentage of GDP, lagged expenditure by one and two years, restricted

Table 2. Descriptive characteristics of the primary analytical sample (N=2,916 country-years)

Variable	N	Mean	SD	Median	IQR	Range
Health expenditure, PPP \$/capita	2916	423.5	413.8	282.9	117.7-606.1	6.1-3089.3
Life expectancy, years	2916	66.4	7.5	67.7	61.6-72.3	31.5-81.0
Infant mortality /1,000	2916	35.6	23.9	29.4	16.2-50.7	1.9-138.5

GDP, gross domestic product; IQR, interquartile range; PPP, purchasing power parity; SD, standard deviation. Sanitation had N=2,856 in the primary life-expectancy sample.

Linear associations

In the bivariate model, a one-unit increase in log expenditure was associated with 5.13 additional life-years (95% CI, 4.44-5.81; $p < .001$). The estimate was 3.20 years (95% CI, 1.25-5.14; $p = .001$) after pooled adjustment and 1.84 years (95% CI, 0.91-2.76; $p < .001$) with country fixed effects. After year fixed effects were added, the estimate changed to -0.30

Table 3. Sequential models of log health expenditure and life expectancy

Model	Coefficient	p	Obs.	Countries	Country	Year
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the period to 2000-2019, and used a balanced pre-pandemic panel. Diagnostics included pooled variance-inflation factors, residual patterns, within-country residual autocorrelation, and leave-one-country-out estimates. Analyses used Python 3.12 with pandas 2.2.3, NumPy 2.3.5, and SciPy 1.17.0.

Ethical considerations

The analysis used publicly available aggregate country-level data and contained no individual records or identifiable personal information. No participants were recruited.

Results

Sample and descriptive characteristics

The eligible dataset contained 131 LMICs and 3,144 possible country-year rows. The primary life-expectancy model included 2,916 observations from 124 countries: 486 observations from 21 low-income countries, 1,078 from 46 lower-middle-income countries, and 1,352 from 57 upper-middle-income countries. Missingness in the eligible panel was 4.1% for health expenditure, 5.3% for GDP, and 0.1% or less for the main outcomes. Median health expenditure was PPP \$282.9 per capita (interquartile range, \$117.7-\$606.1); mean life expectancy was 66.4 years (standard deviation, 7.5).

Under-five mortality /1,000	2916	49.9	40.8	34.9	18.8-69.9	2.4-254.7
GDP per capita, PPP \$	2916	9044.3	6904.6	6840.9	3371.2-13484.2	712.0-39994.6
Urban population, %	2916	48.1	19.7	47.2	31.9-63.1	8.0-92.7
Basic sanitation, %	2856	61.1	29.7	68.4	33.9-89.1	3.0-99.7

years (95% CI, -1.22 to 0.63; $p = .526$). Thus, the positive cross-country and within-country temporal associations were not distinguishable from shared global time trends in the primary specification.

For secondary outcomes, the two-way fixed-effects elasticity of infant mortality with respect to health spending was -0.048 (95% CI, -0.116 to 0.020; $p = .167$), and the under-five mortality elasticity was -0.036 (95% CI, -0.102 to 0.029; $p = .270$). The directions were compatible with improved outcomes, but both CIs included the null.

	(95% CI)				FE	FE
Bivariate	5.13 (4.44)	<.001	3014	129	No	No

	to 5.81)					
Pooled adjusted	3.20 (1.25 to 5.14)	0.0 01	29 16	124	No	No
Coun	1.84	<.0	29	124	Yes	No

Coefficient is the change in life expectancy (years) per one-unit increase in natural-log health expenditure. Adjusted models include log GDP per capita and urban population percentage. Standard errors are clustered by country. Tests were two-sided; $p < .05$ was considered statistically significant. CI, confidence interval; FE, fixed effects; GDP, gross domestic product.

Nonlinearity and heterogeneity

Spline nonlinear terms for life expectancy were jointly significant ($p < .001$). The adjusted curve increased only at the lowest spending values, peaked below approximately PPP \$150 per capita, and then declined modestly across most of the observed range. At the first spending quartile (PPP \$117.7), the estimated change per additional PPP \$100 was 0.71 years (95% CI, -0.11 to 1.53). At the median (PPP \$282.9) and third quartile (PPP \$606.1), estimates

Table 4. Nonlinear, secondary-outcome, and income-group analyses

Outcome	Spending term/specification	Coefficient (95% CI)	p	Obs./countries
Life expectancy	Spending/PPP \$1,000	-6.748 (-9.3312 to -4.1647)	<.001	2916/124
Life expectancy	Spending squared	1.248 (0.5027 to 1.9930)	0.001	2916/124
Log infant mortality	Spending/PPP \$1,000	0.067 (-0.1834 to 0.3179)	0.596	2918/124
Log infant mortality	Spending squared	-0.057 (-0.1406 to 0.0261)	0.177	2918/124
Log under-five mortality	Spending/PPP \$1,000	0.148 (-0.1039 to 0.4000)	0.247	2916/124

try FE	(0.91 to 2.76)	01	16			
Coun try + year FE	-0.30 (-1.22 to 0.63)	0.5 26	29 16	124	Yes	Yes

were -0.73 years (95% CI, -1.14 to -0.31) and -0.42 years (95% CI, -0.58 to -0.27), respectively. Quadratic models produced a similarly non-hypothesized shape for life expectancy; squared terms were not significant for either mortality outcome. These patterns did not meet the study definition of beneficial but progressively diminishing returns.

Income-group interactions were jointly significant ($p < .001$). The log-spending coefficient was 2.25 years in low-income countries (95% CI, 0.88-3.63; $p = .002$), -0.82 years in lower-middle-income countries (95% CI, -1.79 to 0.15; $p = .095$), and -3.07 years in upper-middle-income countries (95% CI, -4.12 to -2.03; $p < .001$). Because income group was fixed at retrieval and the estimates may reflect time-varying endogeneity or measurement differences, these subgroup findings were treated as exploratory.

Log under-five mortality	Spending squared	-0.066 (-0.1509 to 0.0187)	0.125	2916/124
Life expectancy	Log spending: Low income	2.25 (0.88 to 3.63)	0.002	2,916/124
Life expectancy	Log spending: Lower middle income	-0.82 (-1.79 to 0.15)	0.095	2,916/124
Life expectancy	Log spending: Upper middle income	-3.07 (-4.12 to -2.03)	<.001	2,916/124
Log infant mortality	Log spending	-0.048 (-0.116 to 0.020)	0.167	2918/124
Log under-five mortality	Log spending	-0.036 (-0.102 to 0.029)	0.270	2916/124

All models include country and year fixed effects, log GDP per capita, urban population percentage, and country-clustered standard errors. The joint test for the two income-group interactions was $p < .001$. Quadratic linear and squared terms must be interpreted jointly. Tests were two-sided; $p < .05$ was considered statistically significant. CI, confidence interval; GDP, gross domestic product; PPP, purchasing power parity.

Figure 1. Adjusted life expectancy versus current health expenditure per capita. The curve is a four-knot restricted cubic spline from the country and year fixed-effects model; shading indicates the 95% confidence interval. Observed country-year values are shown in gray. Predictions are limited to the 5th-95th percentile spending range.

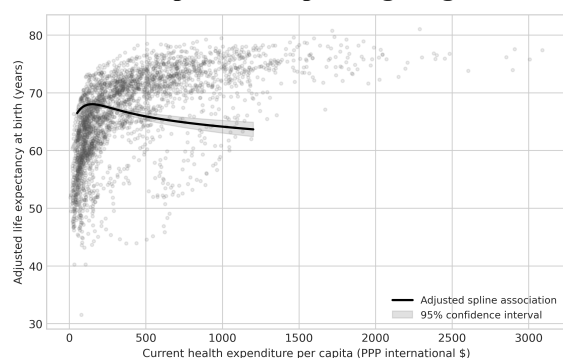
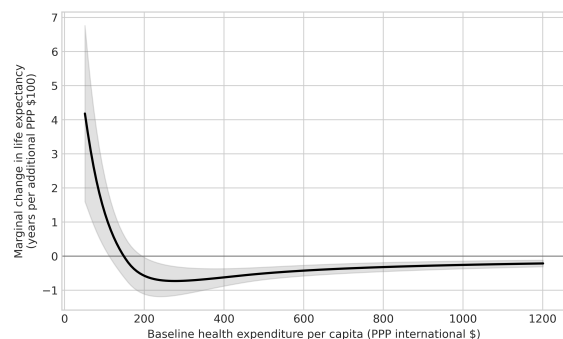


Figure 2. Marginal association between health expenditure and life expectancy across baseline spending. The curve shows the model-estimated change in life expectancy per additional PPP \$100; shading indicates the 95% confidence interval. Values above zero indicate longer predicted life expectancy.



Sensitivity analyses and diagnostics

The primary log-spending estimate remained statistically inconclusive after adding sanitation (-0.35 years; $p = .455$), removing GDP (0.23 years; $p = .600$), using expenditure as a percentage of GDP ($p = .836$), lagging expenditure one or two years ($p = .771$ and $p = .916$), restricting observations to 2000-2019 (-0.01 years; $p = .986$), or using a balanced pre-pandemic panel (0.18 years; $p = .724$). Leave-one-

country-out coefficients ranged from -0.44 to -0.18 years, showing that no single country explained the primary estimate. Pooled variance-inflation factors were 4.50 for spending, 4.60 for GDP, and 1.72 for urbanization. Median residual first-order autocorrelation was 0.91, supporting country-clustered inference and caution about dynamic processes.

Discussion

This study did not find evidence that higher current health expenditure was consistently associated with improving population-health outcomes after stable country characteristics and common year shocks were controlled. Positive estimates in pooled and country-only models disappeared after year fixed effects were added. Infant and under-five mortality estimates pointed toward modest improvement but were imprecise. Flexible models identified nonlinearity, yet the shape was not the hypothesized monotonic benefit with diminishing marginal gains.

The contrast across specifications is substantively important. Health spending and population health both improved over much of 2000-2023, so models without year effects can attribute parallel global progress to expenditure. Year fixed effects ask a more demanding question: whether a country's spending change relative to the common annual pattern corresponded to a contemporaneous change in its health outcome. The null primary estimate suggests that aggregate spending changes alone did not explain those deviations. It does not show that health services lack value or that budgets should be reduced.

The results help reconcile heterogeneous prior studies. Stronger favorable estimates have been reported in selected developing-country and regional panels,⁷⁻¹⁰ while other analyses found weak links after accounting for broader determinants or endogeneity.^{6,11} Governance can modify the productivity of public spending,¹² and meta-analytic evidence shows that results depend on the chosen outcome, design, and spending measure.¹³ The significant income-group interaction also indicates that one pooled slope can conceal different country trajectories. The positive low-income estimate is consistent with greater scope for essential-service expansion at very low resource levels, but the inverse upper-middle-income estimate should not be read causally. Governments may raise spending in response to disease burdens, inefficiency, aging, crises, or higher input prices; these mechanisms can produce a non-positive contemporaneous association even when particular services improve health.

Policy interpretation should therefore separate the amount spent from what spending purchases. Current health expenditure aggregates public, compulsory,

voluntary, and out-of-pocket financing and does not identify allocations to primary care, prevention, workforce, medicines, hospitals, administration, or financial protection. Two countries with equal per-capita expenditure may differ substantially in purchasing arrangements, access, quality, governance, and distribution. Monitoring expenditure composition and service outputs alongside mortality and longevity is more informative than relying on expenditure totals as a performance metric.

The secondary mortality results also warrant restraint. Their negative elasticities were directionally favorable but statistically uncertain, and annual national mortality estimates can change slowly relative to budgets. Longer or service-specific lags may matter, while the one- and two-year sensitivity analyses cannot capture cumulative life-course pathways. Life expectancy incorporates causes of death that health systems influence to different degrees and was disrupted by the coronavirus disease pandemic; the pre-pandemic sensitivity result was nevertheless similarly null.

Strengths include a contemporary 24-year multicountry panel, harmonized authoritative indicators, multiple health outcomes, explicit country and year fixed effects, clustered inference, formal interaction testing, flexible nonlinear analysis, and a fully reproducible audit trail. Limitations are substantial. The ecological design cannot support individual inference. Fixed effects do not remove time-varying confounding, reverse causality, measurement error, or policy endogeneity. The PPP expenditure series is expressed in current

international dollars rather than constant health-sector prices. GDP adjustment may partly absorb pathways through which national resources influence health, although estimates without GDP were also null. Parsimonious adjustment omitted education, age structure, governance, disease burden, and health-service quality; adding mediators could create different bias. Income group was fixed at retrieval and does not represent annual transitions. Residual autocorrelation was high, and country clustering does not fully address cross-country dependence. Spline estimates at distributional tails were less precise and should not be interpreted as spending thresholds. Finally, national averages conceal inequalities and expenditure composition.

Recommendations

LMIC decision-makers should not interpret the absence of a robust aggregate association as a reason to constrain necessary health investment. Budget assessment should link spending to its composition, service coverage, quality, equity, and implementation efficiency. Lower-income settings may benefit from prioritizing high-value essential services, while middle-income settings should examine whether incremental resources address unmet need or higher costs. Future research should combine financing categories with service-output measures, use credible policy changes or instruments where available, model longer distributed lags, and examine distributional outcomes within countries. No universal spending threshold is supported by this analysis.

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