Indo American Journal of Multidisciplinary Research and Review (IAJMRR)
International Peer Reviewed - Refereed Research Journal
ISSN: 2581 - 6292, Impact Factor: 6.885, Website: www.iajmrr.com

PUBLIC PRIVATE AND EXTERNAL HEALTH FINANCING ASSOCIATIONS WITH LIFE EXPECTANCY ACROSS DIVERSE NATIONAL HEALTH SYSTEMS

Kannan Vishwanath* & Lloyd Zulu**
* Garwood Innovation Fellow, Garwood Center for Corporate Innovation, Haas School of Business, Berkeley
** World Christian University, Lusaka, Zambia

Cite This Article: Kannan Vishwanath & Lloyd Zulu, "Public Private and External Health Financing Associations With Life Expectancy Across Diverse National Health Systems", Indo American Journal of Multidisciplinary Research and Review, Volume 9, Issue 2, July - December, Page Number 211-222, 2025.
Copy Right: © IAJMRR Publication, 2025 (All Rights Reserved). This is an Open Access Article distributed under the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.
DOI: https://doi.org/10.5281/zenodo.24039112

Abstract:

This analysis examines whether international health financing gradients persist as annual associations with life expectancy within national systems. An unbalanced panel of 2,377 observations across 180 economies from 2010 through 2023 combines World Bank indicators with ordinary least squares estimation, economy and year effects, and standard errors clustered by economy. Pooled correlations with life expectancy reach 0.804 for transformed government expenditure and 0.767 for private expenditure, but decline to −0.074 and −0.041 after removing economy and year effects. All three baseline financing confidence intervals include zero, and financing explains 0.57 percent of the remaining outcome variation. Restricting analysis to economies with complete annual coverage preserves this interpretation, while entering expenditure in original dollar levels produces a statistically significant negative government association, demonstrating functional form sensitivity. These findings distinguish international financing differences from contemporaneous relationships within economies rather than establish causal transmission channels. The contribution refines financing transition interpretations by showing why pooled gradients cannot directly support expectations of annual survival gains. International budgeting and benchmarking should therefore incorporate uncertainty, reporting coverage and specification sensitivity.

Key Words: Health Financing; Life Expectancy; Panel Data; Fixed Effects; International Health Systems

1. Introduction:

Health financing decisions require evidence about whether additional resources accompany improvements in population survival. International comparisons commonly associate higher expenditure with longer life expectancy, yet differences between national health systems need not describe the relationship between annual spending changes and health outcomes within them. This distinction matters for governments allocating domestic resources, households financing care and international organizations distributing assistance. Interpreting an international spending gradient as an expected return to additional expenditure can overstate what observational evidence establishes. This analysis examines that distinction by comparing government, private and external financing associations with life expectancy across national health systems. Health financing provides resources for prevention and treatment, but expenditure amounts and financing arrangements represent different dimensions of a health system. Kutzin, 2013, explains that financing should be assessed through its contribution to population outcomes, access and financial protection. Fan and Savedoff, 2014, describe a health financing transition involving rising expenditure and changes in how resources are pooled. Together, these perspectives imply that greater financing capacity can accompany improved health without establishing a uniform relationship between annual expenditure increases and survival. Financing sources may differ in their allocation and payment arrangements, while expenditure can also respond to deteriorating health conditions.

Domestic government financing can distribute resources beyond individual purchasing power and support services whose benefits extend across populations. Domestic private financing can supplement available resources, but its aggregate expenditure measure combines voluntary prepayment with direct payments for care. External financing can expand the resources available to national systems while interacting with domestic budget decisions. Lu and colleagues, 2010, document substitution between assistance channelled through governments and domestically financed public expenditure. Consequently, increases from different financing sources cannot automatically be interpreted as equivalent additions to effective care. Examining the components jointly preserves these distinctions without treating their coefficients as independently identified policy effects. The closest empirical evidence establishes relationships between financing, coverage and population health, but its interpretation depends on the measures and timing examined. Moreno Serra and Smith, 2015, connect broader health coverage and pooled financing with improved population health using national panel data. Bendavid and Bhattacharya, 2014, report associations between health assistance and subsequent improvements in life expectancy and child mortality. These contributions address financing arrangements, coverage or health improvements

following assistance. They do not directly settle whether contemporaneous associations between three aggregated expenditure sources and life expectancy remain comparable when pooled differences are separated from variation within economies.

Life expectancy at birth provides a common population outcome for this comparison. It summarizes expected survival under prevailing mortality conditions rather than the completed lifespan of an observed birth cohort. Its breadth supports comparisons across health systems, but it does not isolate the contribution of health expenditure from other determinants of mortality. We therefore retain its demographic meaning and interpret financing coefficients as conditional associations. Likewise, expenditure measured in current US dollars per capita captures nominal financial inputs rather than constant purchasing power, service coverage or treatment effectiveness. These measurement boundaries define the question that the available data can answer. This study aims to determine how domestic government, domestic private and external health expenditure per capita are associated with life expectancy across national health systems. The research question asks whether pooled financing associations persist after accounting for economy and year effects, and whether the resulting estimates remain stable across sample and expenditure specifications. The analysis uses 2,377 annual observations across 180 economies from 2010 through 2023. It combines descriptive comparisons with a regression containing the three financing components, economy effects and year effects, with standard errors clustered by economy. Sensitivity analyses examine a balanced panel, an alternative expenditure scale and the exclusion of an economy with unusually low reported life expectancy observations.

The findings contribute by demonstrating a marked separation between pooled financing gradients and adjusted annual associations. Strong positive pooled correlations for domestic financing contract substantially after removing economy and year effects. The baseline conditional estimates remain imprecise, while the precision of the government association changes when expenditure enters in original dollar levels. This evidence qualifies the use of international spending comparisons as benchmarks for annual survival gains. Its practical contribution is to distinguish what financing differences reveal about observed national systems from what they establish about expenditure changes within them. The analysis thereby supports more disciplined interpretation of international financing evidence without assigning causal meaning to coefficient signs or treating statistical imprecision as evidence that financing has no value.

2. Theory, Conceptual Framework and Hypothesis Development:

This analysis draws on health production theory and the health financing framework to examine how financing sources relate to population survival. Health expenditure provides resources for prevention and treatment, but its relationship with life expectancy depends on how those resources reach patients. Governments, households and external funders operate within the same health system, so expenditure from one source may complement or replace expenditure from another. Kutzin, 2013, establishes that financing arrangements should be assessed through their contribution to population outcomes rather than the performance of individual financing schemes. We therefore examine domestic government, domestic private and external health expenditure jointly, with life expectancy at birth as the observed outcome. Domestic government health expenditure represents public spending financed from domestic sources, measured per capita. Its theoretical contribution arises from the capacity to finance services collectively and distribute resources beyond individual purchasing power. When additional public resources support effective prevention and treatment, greater expenditure should correspond to longer life expectancy. This expectation concerns the conversion of financial resources into health improvements rather than expenditure growth alone.

The relationship need not be uniformly positive. Additional spending may respond to deteriorating health conditions, while differences in allocation can weaken the connection between expenditure and survival. Moreno Serra and Smith, 2012, conclude that broader health coverage generally improves access and population health, while identifying institutional conditions and methodological constraints that qualify this relationship. Their evidence supports a beneficial theoretical pathway without establishing that every increase in government expenditure produces an equivalent health improvement. Evidence from national panel data further connects broader coverage and pooled financing with improved population health. Moreno Serra and Smith, 2015, provide empirical support for this relationship, although financing sources can substitute for one another. Accordingly, this analysis evaluates government expenditure conditional on the other measured financing components, country effects and year effects. The hypothesis retains an unrestricted direction because the available expenditure measure captures financial inputs rather than the effectiveness of their use.

H1: Domestic government health expenditure per capita is associated with life expectancy at birth, conditional on domestic private expenditure, external expenditure, country effects and year effects.

Domestic private health expenditure comprises spending financed by households, corporations and nonprofit organizations, including voluntary prepayment and direct payment for services. Additional private resources can support treatment and expand service availability. However, financing care through individual purchasing power can also constrain access when payment becomes necessary at the point of illness. The aggregate measure therefore combines arrangements with potentially different implications for

population survival. These competing pathways prevent a defensible uniform directional prediction. Higher private expenditure may accompany improved access, but it may also reflect greater treatment costs or spending concentrated among populations already able to obtain care. A larger recorded expenditure amount does not establish that access has broadened. We therefore interpret private expenditure as an observed financing input rather than a direct measure of financial protection or service coverage. The distinction between financing amounts and financing arrangements is central to the framework. The private expenditure indicator does not separately identify the contributions of voluntary prepayment and direct household payments. Its estimated association consequently represents the relationship of their combined expenditure with life expectancy. A hypothesis without a predetermined sign preserves this measurement boundary and permits positive, negative or statistically inconclusive outcomes.

H2: Domestic private health expenditure per capita is associated with life expectancy at birth, conditional on domestic government expenditure, external expenditure, country effects and year effects.

External health expenditure captures financial resources entering the national health system from foreign sources. Such resources can relax domestic financing constraints and support services that would otherwise remain insufficiently funded. The theoretical expectation is that additional resources can improve survival when they expand effective prevention and treatment. Bendavid and Bhattacharya, 2014, report associations between health aid and improvements in life expectancy, providing evidence consistent with this pathway. External resources may also change domestic financing decisions. Lu and colleagues, 2010, identify substitution between assistance channelled through governments and domestically financed government health expenditure. This finding means that an increase in external expenditure need not represent an equivalent increase in total resources. Its relationship with life expectancy must therefore be considered alongside domestic financing rather than interpreted in isolation. The external expenditure indicator combines foreign financial inflows without identifying the effectiveness of individual programmes. This analysis consequently tests its conditional association with life expectancy rather than attributing changes in survival to particular interventions. A hypothesis without a predetermined direction accommodates both the resource expansion mechanism and the possibility that external funding responds to greater health needs.

H3: External health expenditure per capita is associated with life expectancy at birth, conditional on domestic government expenditure, domestic private expenditure, country effects and year effects.

The conceptual framework comprises three observed financing measures linked to one observed population outcome. We retain the financing components separately rather than constructing a composite index. Each relationship represents a conditional association with life expectancy, with country effects accounting for stable national characteristics and year effects accounting for shared annual influences. The hypotheses correspond to separate tests of the three financing coefficients and do not imply that the observational design identifies causal effects.

3. Data:

This analysis documents data provenance, constructs the analytical sample and translates health financing into observed expenditure measures. Consistent identifiers, annual timing and explicit missingness rules connect these measures with life expectancy and support reproducible comparisons across health systems.

3.1 Data Sources, Population, and Sample Construction:

The analysis uses four annual series distributed through the World Bank World Development Indicators database. Domestic government, domestic private and external health expenditure originate from the World Health Organization Global Health Expenditure Database. Life expectancy originates from the demographic sources identified in the World Bank metadata, including the United Nations Population Division. The supplied workbook records the original retrieval timestamp, provider update dates and extraction URLs. It contains revised historical observations rather than a frozen release available at each observation date. The source architecture distinguishes financing origin from the institutions delivering care. This distinction follows the health accounting boundaries established by the OECD, Eurostat and World Health Organization, 2011, and the financing framework developed by the World Health Organization, 2010. The World Bank, 2013, describes the compilation of internationally reported development indicators, while the World Health Organization, 2023, documents international health expenditure reporting. United Nations, 2022, provides the demographic basis for interpreting period life expectancy. These publications establish concepts and reporting context rather than identify the vintage of the supplied extract.

The unit of analysis is an economy observed in a calendar year. The observation window extends from 2010 through 2023, covering national health systems across geographical regions and income settings. Expenditure measures represent annual financing flows per person. Life expectancy represents expected survival under prevailing mortality conditions rather than the completed lifespan of an observed birth cohort. The target population comprises national health systems with conceptually comparable expenditure and survival measures. The accessible frame contains 217 economies and 3,038 annual records. Selection follows data availability rather than probability sampling. World Bank regional and

income aggregates are absent from the supplied source panel. Records enter the analytical sample when all four required measures are observed.

Table 1: Sample construction

Stage	Economies Retained	Observations Retained	Implemented Rule
Accessible frame within the observation window	217	3,038	Annual economy records from 2010 through 2023
Government and private financing available	193	2,675	Exclude 363 records missing either domestic financing measure
External financing also available	180	2,377	Exclude another 298 records missing external expenditure
Life expectancy available	180	2,377	No additional exclusions
Baseline estimation sample	180	2,377	Contemporaneous measures and economy and year effects
Balanced panel sensitivity sample	152	2,128	Retain economies observed in all 14 years

The baseline panel is unbalanced. Of the 180 retained economies, 152 contribute all 14 annual observations; the remaining 28 contribute between two and thirteen observations. Complete annual coverage ranges from 163 economies in 2010 to 174 in 2020. The window restriction was applied before the present estimation. The workbook does not contain a dated preregistration establishing when its original eligibility rules were adopted. Access is through the World Bank Indicators API and the stable series pages identified in Table 3. World Bank dataset terms generally permit reuse under Creative Commons Attribution 4.0, subject to attribution and applicable third party restrictions. Public access does not imply that every underlying series carries identical redistribution rights.

3.2 Data Integration, Cleaning, and Quality Assurance:

We reconstructed the source panel using the economy identifier and calendar year as the unique key. The audit identified no duplicate keys among the 3,038 records. Repeated observations across years represent the panel structure rather than duplication. All financing records were aligned with life expectancy for the same economy and year. No frequency conversion, researcher currency conversion, inflation adjustment or additional population division was applied. The expenditure series remain in current United States dollars per capita. Consequently, changes reflect nominal financing movements together with exchange rate and price movements. They do not measure changes in purchasing power at constant prices. The analysis uses the supplied historical revisions and does not reconstruct the information available to policymakers at each observation date.

Missingness was assessed before complete record selection. Government and private expenditure each contain 363 unavailable observations, representing 11.95 percent of the accessible frame. External expenditure contains 661 unavailable observations, representing 21.76 percent. Life expectancy is observed throughout the frame. At least one missing observation occurs in 31 economies for each domestic financing measure and in 65 economies for external financing.

Table 2: Annual availability before sample restriction

Year	Government Expenditure Observed	Private Expenditure Observed	External Expenditure Observed	Life Expectancy Observed	Complete Records
2010	188	188	163	217	163
2011	189	189	165	217	165
2012	189	189	166	217	166
2013	191	191	169	217	169
2014	191	191	168	217	168
2015	191	191	168	217	168
2016	191	191	170	217	170
2017	192	192	171	217	171
2018	193	193	173	217	173
2019	193	193	171	217	171
2020	193	193	174	217	174
2021	192	192	173	217	173
2022	191	191	173	217	173
2023	191	191	173	217	173

Missing financing values remain unavailable rather than being recoded as zero. The source panel contains 331 reported external expenditure zeros, which retain their numerical meaning. No imputation or interpolation was implemented. Reporting observed missingness separately from assumptions about its causes follows Lee and colleagues, 2021, and Seaman and colleagues, 2013. Complete record selection does not establish that excluded observations are exchangeable with retained observations. Mean life expectancy equals 70.56 years among retained records and 78.18 years among excluded records. This descriptive difference demonstrates that coverage restrictions change sample composition. Hughes and colleagues, 2019, and Carpenter and Smuk, 2021, explain why the validity of complete record analysis depends on the missingness process and analytical model. Madley Dowd and colleagues, 2019, further establish that the proportion missing alone cannot determine the appropriate treatment. The reported associations therefore concern the observed sample rather than a representative estimate for every national health system.

Numerical checks identified no negative financing values, nonfinite analytical values or life expectancy observations outside the screening interval above zero and at most 120 years. No observations were trimmed or winsorized. The minimum life expectancy observation, 18.818 years for the Central African Republic in 2022, was reproduced in the provider series and retained without alteration. Provider agreement establishes transcription consistency rather than independent demographic validation.

3.3 Variable Measurement, Construction, and Validation:

Health financing is represented by three separately observed expenditure components. We do not combine them into a composite score. Government expenditure captures domestic public resources, private expenditure combines domestic private financing arrangements, and external expenditure captures resources originating outside the economy. Life expectancy at birth provides the common population outcome.

Table 3: Variable dictionary

Variable	Analytical Role	Definition and Construction	Source and Identifier	Unit and Frequency	Transformation and Direction	Missing Value Rule	Coverage and Limitation
Domestic government health expenditure	Predictor	Provider reported public health expenditure financed from domestic sources per person	WHO through WDI	Current US dollars per capita; annual	Natural logarithm of one plus expenditure; higher values indicate greater domestic public financing	Exclude incomplete records	2,675 source observations; nominal financing rather than service effectiveness
Domestic private health expenditure	Predictor	Provider reported domestic private expenditure per person, including voluntary prepayment and direct payments	WHO through WDI	Current US dollars per capita; annual	Natural logarithm of one plus expenditure; higher values indicate greater domestic private financing	Exclude incomplete records	2,675 source observations; does not isolate household payments from other private arrangements
External health expenditure	Predictor	Provider reported health expenditure financed from foreign sources per person	WHO through WDI	Current US dollars per capita; annual	Natural logarithm of one plus expenditure; reported zeros retained	Exclude incomplete records	2,377 source observations; does not identify individual programmes
Life expectancy at birth	Outcome	Expected years of survival under prevailing mortality conditions	WDI	Years; annual	Untransformed; higher values indicate longer expected survival	Exclude incomplete records	3,038 source observations; population measure rather than individual survival history

Equation 1 defines the implemented expenditure transformation:

$$Z_{kit} = \ln[1 + X_{kit}]$$

Here, X_{kit} denotes expenditure component k in economy i and year t, and Z_{kit} denotes its transformed value. The index k identifies government, private or external financing. Adding one retains observed zeros and reduces expenditure skewness. This construction is a transformation of expenditure levels rather than an expenditure growth rate or percentage change. The distinction between financial inputs and health system performance follows Kutzin, 2013. Moreno Serra and Smith, 2012, and Moreno Serra and Smith, 2015, connect financing and coverage with population health but do not establish that expenditure alone measures access or effectiveness. Accordingly, the indicators retain their accounting meaning rather than being relabelled as coverage or financial protection measures. External financing is retained separately because assistance can accompany health improvements while also interacting with domestic spending. Bendavid and Bhattacharya, 2014, provide evidence relating health assistance to population health, while Lu and colleagues, 2010, document substitution between external assistance and domestic government financing. These findings justify distinguishing financing origins without treating the observed components as independent policy interventions.

Table 4: Descriptive statistics for the analytical sample

Variable	Valid Observations	Mean	Standard Deviation	Median	Minimum	Maximum
Government expenditure per capita	2,377	625.00	1,222.81	140.39	0.46	7,871.24
Private expenditure per capita	2,377	314.60	691.19	99.22	0.84	7,885.33
External expenditure per capita	2,377	17.82	50.68	4.86	0.00	522.08
Life expectancy at birth	2,377	70.56	7.95	71.30	18.82	84.56

The expenditure means exceed their medians, indicating concentration toward higher spending observations. Equal analytical counts reflect complete record selection rather than complete source coverage. Validation comprises identifier checks, numerical screening, transformation checks and targeted provider verification. The measures are observed secondary indicators, so internal consistency coefficients and factor analysis do not apply.

3.4 Analytical Framework, Identification, and Reproducibility:

The analysis estimates conditional associations between financing components and life expectancy. Equation 2 specifies the implemented baseline:

$$L_{it} = \alpha_i + \lambda_t + \beta_G Z_{Git} + \beta_P Z_{Pit} + \beta_E Z_{Eit} + \varepsilon_{it}$$

Here, L_{it} denotes life expectancy in economy i and year t. The term α_i represents economy effects, and λ_t represents year effects. The variables Z_{Git}, Z_{Pit} and Z_{Eit} are the transformed government, private and external expenditure measures defined in Equation 1. The coefficients β_G, β_P and β_E describe their conditional associations with life expectancy. The term ε_{it} represents the residual. We estimated Equation 2 by ordinary least squares with economy and year indicators. Identification of the coefficients uses financing variation within economies after accounting for shared annual shifts. The three financing predictors retain full rank after removing economy and year effects. Bell and colleagues, 2019, explain the distinction between within economy and between economy relationships that motivates this specification.

Inference uses standard errors clustered across 180 economies, with a finite sample adjustment and a reference distribution with 179 degrees of freedom. This permits heteroskedasticity and residual dependence within an economy. It does not automatically accommodate residual dependence between economies. Cameron and Miller, 2015, provide the basis for this clustering approach and its limitations. Economy effects absorb stable national differences, while year effects absorb common annual shifts. They do not remove every changing source of confounding or establish that financing precedes health outcomes. Imai and Kim, 2019, clarify the assumptions required for causal interpretations of unit effects models; Imai and Kim, 2021, further show that combining unit and time effects remains dependent on modelling assumptions. We therefore interpret Equation 2 as an associational specification.

Two exploratory sensitivity specifications were estimated after the baseline. The first restricted the analysis to 152 economies with complete annual coverage, retaining 2,128 observations. This comparison addresses changes in panel composition. The second replaced transformed expenditure with original expenditure levels while retaining all 2,377 baseline observations. This comparison addresses dependence on functional form. Neither exercise establishes protection against omitted variable bias, whose implications for regression interpretation are developed by Cinelli and Hazlett, 2020. Reconstruction uses the supplied source panel, fixed series identifiers, economy and year keys, the stated observation window and the completeness rule in Table 1. The audit code retains the original values and reproduces selection, descriptive statistics, transformations and estimation. Consistent timing and measurement make the financing components comparable within the specified model, while nominal currency measurement and selective source coverage delimit its interpretation.

4. Methods:

4.1 Research Design and Identification Strategy:

This analysis uses an observational annual panel to examine conditional associations between three financing sources and life expectancy. The unit of analysis is an economy observed in a calendar year from 2010 through 2023. The research question distinguishes pooled international associations from relationships estimated after accounting for persistent economy differences and shared annual variation. The estimands are the partial regression coefficients relating each financing component to life expectancy, conditional on the other components and economy and year effects. Financing and survival are measured contemporaneously. The design compares expenditure variation within economies after removing common annual shifts rather than comparing treated and untreated populations. Economy effects absorb national characteristics that remain constant over the observation window. Year effects absorb annual influences shared across economies. This adjustment distinguishes within economy relationships from pooled differences, following Bell and colleagues, 2019. It does not remove changing national influences, expenditure responses to health conditions or measurement error. The coefficients therefore represent conditional associations. Causal interpretation would require stronger assumptions about the relationship

between financing and unobserved determinants of survival than the design establishes. Imai and Kim, 2021, demonstrate that including unit and time effects does not itself provide a causal identification strategy. Accordingly, coefficient signs are interpreted as features of the specified observational relationship rather than consequences of financing interventions.

4.2 Model Specification and Measurement Alignment:

The baseline implements Equation 2, with life expectancy as the outcome and government, private and external expenditure entered jointly. Equation 1 transforms each financing component using the natural logarithm of one plus expenditure. Table 3 provides the definitions, source identifiers, units and missingness rules. The transformation accommodates reported external financing zeros and reduces the influence of differences in expenditure scale. Higher transformed values retain the interpretation of greater expenditure per capita. Life expectancy remains in years. All observations receive equal weight, so the model estimates relationships across economy and year records rather than across individuals or population weighted national averages. We include economy and year indicators with an intercept and omit one reference category from each indicator set. The baseline design matrix has full column rank. The three financing predictors also retain full rank after removing economy and year effects, establishing that their coefficients are separately estimable from the available variation. For interpretation, we translate a change in expenditure into a fitted difference in life expectancy using Equation 3:

$$\Delta\hat{L}_k = \hat{\beta}_k \ln\left[\frac{1 + x_b}{1 + x_a}\right]$$

Here, $\Delta\hat{L}_k$ is the fitted difference in life expectancy associated with changing financing component k. The term $\hat{\beta}_k$ is its estimated coefficient from Equation 2, while x_a and x_b are the initial and comparison expenditure amounts in current US dollars per capita. Other financing components and fixed effects remain unchanged. Confidence limits for this contrast multiply the coefficient limits by the same logarithmic difference. This interpretation accounts for the addition of one in Equation 1. A doubling of expenditure therefore does not correspond exactly to multiplying the coefficient by the natural logarithm of two. The original expenditure sensitivity model instead expresses coefficients as years of life expectancy per additional US dollar per capita.

4.3 Sample Construction, Estimation and Inference:

Table 1 documents the selection sequence. We restricted the supplied source panel to the observation window, verified unique economy and year identifiers, and retained records with all four analytical measures. The baseline contains 2,377 observations across 180 economies. The unbalanced structure permits economies with incomplete annual coverage to contribute their available complete records. Missing values were not replaced with zero. Reported external financing zeros were preserved. No imputation, interpolation or expenditure trimming was applied. Complete record selection defines the estimation sample but does not establish that excluded observations have the same distribution as retained observations. Hughes and colleagues, 2019, explain why the validity of this approach depends on the missingness process and substantive model.

We estimated the baseline by ordinary least squares using an explicit matrix containing the financing predictors, intercept, economy indicators and year indicators. Computation used Python 3.12.14, NumPy 2.3.5, pandas 2.2.3 and SciPy 1.17.0. NumPy least squares used its default numerical rank tolerance. The baseline matrix contains 196 linearly independent columns. Standard errors use an economy clustered sandwich covariance estimator. For each economy, we summed the products of its regressor vectors and fitted residuals, then formed the covariance matrix from the outer products of these economy score sums. The calculation applies the finite sample multiplier $\frac{G}{[G-1]}$ multiplied by $[N-1]/[N-K]$, where G is the number of economies, N is the observation count and K is the design matrix rank. The baseline uses 180 clusters. Individual coefficient tests and 95 percent confidence intervals use a student reference distribution with 179 degrees of freedom. The joint test evaluates whether all three financing coefficients equal zero, using a Wald statistic divided by three and an F reference distribution with three numerator and 179 denominator degrees of freedom. This procedure accommodates heteroskedasticity and residual dependence within economies, following Cameron and Miller, 2015. Its interpretation remains conditional on adequate independence between economy clusters.

4.4 Diagnostics, Sensitivity and Reproducibility:

The diagnostic sequence examines the variation relevant to the estimator. We first calculated pooled Pearson correlations between transformed financing and life expectancy. We then separately regressed each measure on economy and year indicators and calculated correlations between the resulting residuals. Table 6 therefore compares pooled associations with associations after removing the same fixed effects used in the baseline. Collinearity assessment also uses residualized financing measures. Each residualized predictor was regressed on the other two, and its variance inflation factor was calculated from the resulting coefficient of determination. This evaluates overlap in the financing variation available for coefficient estimation rather than overlap driven by persistent national differences. Model fit was assessed relative to a regression containing only economy and year indicators. The reported incremental explanatory proportion equals one minus the baseline residual sum of squares divided by the residual

sum of squares from that restricted regression. It measures the additional variation explained by the financing components after the fixed effects have been accounted for. Table 8 reports three exploratory sensitivity exercises conducted after baseline estimation. The balanced panel specification retains 2,128 observations across 152 economies with complete coverage in all fourteen years. It assesses dependence on changing panel composition. The original expenditure specification retains the baseline sample and changes only the financing scale, separating functional form sensitivity from sample changes.

The economy exclusion specification removes the fourteen Central African Republic observations, leaving 2,363 records across 179 economies. This exercise assesses sensitivity to its unusually low reported life expectancy observations without altering the baseline source values. Each sensitivity model retains the joint financing specification and economy and year effects. Cluster counts, numerical ranks and reference degrees of freedom are recalculated for the corresponding sample. Comparisons consider coefficient direction, magnitude and uncertainty rather than statistical significance alone. The implementation preserves source values and records the observation window, completeness rule, transformations, indicator construction, covariance adjustment and sensitivity restrictions. These procedures make the reported comparisons reproducible while keeping their interpretation aligned with an observational design.

5. Findings:

This analysis examines how government, private and external health financing relate to life expectancy across national health systems. The findings distinguish pooled associations from relationships estimated after accounting for economy and year effects. Sample comparisons and sensitivity estimates establish the precision and stability of the observed relationships. The analytical sample contains 2,377 annual observations across 180 economies from 2010 through 2023. Requiring complete financing and life expectancy measures excludes 661 observations from the accessible frame of 3,038 records. Of the retained economies, 152 contribute all fourteen years. Mean life expectancy equals 70.56 years among retained observations and 78.18 years among excluded observations. This difference indicates that financing availability changes sample composition. Consistent with Hughes and colleagues, 2019, complete record selection should therefore be interpreted as defining the observed analytical population rather than establishing representativeness.

Table 5: Distribution of financing and life expectancy in the analytical sample

Measure	Observations	Mean	Standard Deviation	Median	Minimum	Maximum
Government expenditure per capita	2,377	625.00	1,222.81	140.39	0.46	7,871.24
Private expenditure per capita	2,377	314.60	691.19	99.22	0.84	7,885.33
External expenditure per capita	2,377	17.82	50.68	4.86	0.00	522.08
Life expectancy at birth	2,377	70.56	7.95	71.30	18.82	84.56

Table 5 shows substantial dispersion in financing. Government expenditure has a mean exceeding four times its median, while external expenditure has a mean exceeding three times its median. These distributions indicate that arithmetic averages are influenced by higher spending observations. Government and private expenditure remain positive throughout the analytical sample, whereas external expenditure includes reported zeros. The regression transformation therefore uses the natural logarithm of one plus expenditure for all three components. The balanced sample provides a comparison unaffected by changes in economy membership. Across its 152 economies, average government expenditure increased from US$482.58 per capita in 2010 to US$719.51 in 2023. Private expenditure increased from US$266.77 to US$371.51, while external expenditure increased from US$17.44 to US$23.47. Over the same interval, average life expectancy increased from 68.41 to 71.77 years. These parallel movements describe aggregate trajectories; they do not establish that financing increases explain the improvement in survival.

The annual pattern also contains a marked interruption. Within the balanced sample, average life expectancy declined from 70.83 years in 2019 to 69.68 years in 2021, while government expenditure increased from US$588.46 to US$722.24 per capita. Financing and survival therefore did not move uniformly together over the observation window. The contemporaneous specification captures this divergence without identifying whether expenditure responded to deteriorating health conditions.

Table 6: Pooled and adjusted correlations with life expectancy

Financing Measure	Pooled Correlation	Correlation After Removing Economy and Year Effects
Government expenditure	0.804	−0.074
Private expenditure	0.767	−0.041
External expenditure	−0.523	−0.0001

Table 6 identifies the central empirical distinction. Government and private financing have strong positive pooled correlations with life expectancy, but these relationships become small and negative after removing stable economy differences and shared annual variation. The negative pooled correlation for

external financing similarly contracts toward zero. Consequently, the pooled pattern does not describe the relationship between annual financing changes and survival within economies after those adjustments. This distinction qualifies comparisons with evidence linking broader health coverage to improved population health. Moreno Serra and Smith, 2015, examine coverage and financing relationships using national panel data. The present findings concern expenditure inputs and contemporaneous life expectancy, so the attenuation in Table 6 should not be interpreted as evidence against the benefits of effective service coverage.

Table 7: Conditional associations between financing and life expectancy

Financing Predictor	Coefficient	Clustered Standard Error	Lower 95 Percent Confidence Limit	Upper 95 Percent Confidence Limit	p Value
Government expenditure	−0.394	0.235	−0.858	0.070	0.096
Private expenditure	−0.110	0.348	−0.796	0.576	0.752
External expenditure	−0.010	0.088	−0.183	0.163	0.908

Table 7 shows that none of the three baseline confidence intervals excludes zero at the 5 percent significance level. Government expenditure has the largest negative point estimate, but its interval permits both a negative association and a small positive association. At the sample median, doubling government expenditure from US$140.39 to US$280.78 corresponds to an estimated difference of −0.272 years in life expectancy, with a 95 percent confidence interval from −0.592 to 0.048 years. This is a conditional model contrast rather than an estimated causal consequence of increasing expenditure. Private expenditure has a wider interval relative to its point estimate. Its estimated coefficient of −0.110 is compatible with associations ranging from −0.796 to 0.576 years per unit increase in transformed expenditure. External expenditure has a point estimate close to zero, but its interval also permits associations in either direction. These estimates indicate limited precision rather than demonstrating that either financing source has no relationship with survival.

The three financing coefficients are not jointly distinguishable from zero in the baseline model. The clustered joint test yields an F statistic of 0.987 with three numerator and 179 denominator degrees of freedom, with p equal to 0.400. Relative to a specification containing only economy and year effects, the financing measures explain 0.57 percent of the remaining variation in life expectancy. The clustering procedure allows residual dependence within economies, following Cameron and Miller, 2015; it does not establish independence between economies. Predictor overlap is limited in the variation used for estimation. After removing economy and year effects, variance inflation factors equal 1.135 for government expenditure, 1.135 for private expenditure and 1.002 for external expenditure. The adjusted correlation between government and private financing is 0.344. Thus, the imprecision in Table 7 does not coincide with substantial linear redundancy among the adjusted financing predictors.

Table 8: Exploratory sensitivity estimates

Specification	Observations	Economies	Financing Predictor	Coefficient	Lower 95 Percent Confidence Limit	Upper 95 Percent Confidence Limit	p Value
Balanced panel	2,128	152	Government	−0.396	−0.892	0.099	0.116
Balanced panel	2,128	152	Private	−0.268	−0.922	0.386	0.420
Balanced panel	2,128	152	External	−0.011	−0.193	0.171	0.907
Excluding Central African Republic	2,363	179	Government	−0.345	−0.795	0.105	0.132
Excluding Central African Republic	2,363	179	Private	0.002	−0.652	0.656	0.996
Excluding Central African Republic	2,363	179	External	0.011	−0.159	0.182	0.896
Original expenditure levels	2,377	180	Government	−0.000566	−0.000925	−0.000207	0.002
Original expenditure levels	2,377	180	Private	−0.000809	−0.001672	0.000053	0.066
Original expenditure levels	2,377	180	External	−0.001291	−0.004631	0.002049	0.447

Restricting the sample to economies with complete annual coverage leaves the government and external financing estimates close to their baseline values. The private expenditure coefficient becomes more negative, but its confidence interval continues to include zero. The balanced sample therefore preserves the baseline conclusion of limited evidence for a precisely estimated contemporaneous association. The economy exclusion exercise addresses the unusually low reported life expectancy observations for the Central African Republic, including 18.818 years in 2022. Excluding its fourteen observations reduces the magnitude of the government coefficient and changes the private and external coefficients to small positive values. All three confidence intervals still include zero. The baseline

conclusion is therefore unchanged, while the private and external coefficient signs prove sensitive to this exclusion.

Changing the financing scale produces a more consequential difference. With expenditure entered in original dollar levels, the government coefficient is negative and statistically distinguishable from zero. An additional US$100 per capita corresponds to −0.057 years of life expectancy, with a 95 percent confidence interval from −0.092 to −0.021 years. Because the transformed baseline does not provide an equally precise estimate, this negative association depends on functional form. It does not establish an adverse causal effect of government financing. The external financing results also differ from evidence relating health assistance to improvements in population health reported by Bendavid and Bhattacharya, 2014. Their findings concern assistance and subsequent health improvements, whereas the present model relates contemporaneous external expenditure to life expectancy. The near zero baseline estimate therefore addresses a narrower relationship and does not evaluate the effectiveness of individual assistance programmes. The evidence establishes strong pooled financing gradients but weak and imprecise conditional associations after accounting for economy and year effects. Sample balancing preserves this result, while expenditure scaling changes the precision of the government association. Consistent with Imai and Kim, 2021, the fixed effects specification remains dependent on its modelling assumptions. The findings support a distinction between international financing differences and annual associations within economies; they do not establish that additional financing reduces survival or that its contribution is absent.

6. Discussion:

Higher health spending distinguishes economies with longer life expectancy more clearly than it explains annual changes in survival within them. Table 6 shows that strong pooled associations for domestic financing contract substantially after removing economy and year effects. The conditional estimates in Table 7, obtained through Equation 2, remain imprecise despite limited predictor redundancy. This analysis therefore contributes an empirical distinction between international financing gradients and contemporaneous relationships within national systems. Fan and Savedoff, 2014, conceptualize rising expenditure and changing financing composition as a health financing transition. Our findings qualify how that transition should be interpreted: differences associated with national financing trajectories cannot automatically be translated into expected annual survival gains from additional expenditure. The contribution concerns the scale and timing of the observed relationship rather than evidence that financing lacks value. The attenuation between pooled and adjusted associations establishes a boundary for interpreting financing mechanisms. Equations 1 and 2 distinguish expenditure inputs and their conditional relationships with survival, while Tables 6 and 7 show that these relationships change when persistent national differences and common annual variation are removed. This adjustment does not identify how resources reach patients. Kruk and colleagues, 2018, demonstrate that health care utilization and service quality make distinct contributions to mortality outcomes. Their evidence clarifies why expenditure amounts cannot substitute for measures of effective care. The present analysis adds that financing gradients alone provide insufficient grounds for attributing survival differences to a particular transmission pathway. Its theoretical implication is to distinguish the availability of financial resources from the processes through which those resources produce health.

The relative sizes of the financing coefficients do not establish the dominance of one financing channel. Although government expenditure has the largest absolute coefficient in Table 7, its confidence interval includes zero, and the transformation in Equation 1 prevents direct interpretation as a share of a total health effect. Table 8 further shows that entering expenditure in original dollar levels changes the precision of the government association. Jowett and colleagues, 2016, explain why expenditure targets cannot provide a universal benchmark for health system performance. Our findings extend this caution to empirical comparisons: a financing source cannot be ranked by coefficient size without considering scale, uncertainty and specification. The evidence supports evaluating the three financing components jointly while resisting an unsupported hierarchy of their contributions to survival. The sensitivity results reveal that international financing comparisons depend on both observational coverage and the treatment of unusual national trajectories. Table 5 documents concentrated expenditure distributions, while Table 8 shows that excluding the Central African Republic changes the private and external coefficient signs without producing precise associations. Restricting the panel to economies with complete annual coverage preserves the broader baseline interpretation. These results separate conclusions that persist across sample definitions from coefficient directions that depend on particular observations. The Global Burden of Disease Health Financing Collaborator Network, 2017, documents substantial international variation in financing levels and composition. Our contribution is to show why this heterogeneity requires caution when a common specification such as Equation 2 is used to summarize annual relationships across diverse systems. Neither isolated coefficient signs nor pooled averages provide a sufficient basis for identifying operational inefficiency or financing failure.

The global relevance lies in redirecting the interpretation of financing evidence toward the relationship actually measured. Reeves and colleagues, 2015, connect taxation structures with public financing, coverage and selected health outcomes in economies with lower and middle incomes. Our

results concern a broader economy sample, aggregated expenditure sources and contemporaneous life expectancy; their imprecision therefore does not overturn evidence concerning more specific financing arrangements. Instead, Tables 6 through 8 show that international spending gradients, annual conditional associations and specification sensitivity answer different questions. Decision makers should avoid using the negative point estimates from Equation 2 to justify expenditure reductions or using pooled correlations to promise immediate survival gains. The theoretical refinement is to separate financing capacity from its annual association with population outcomes. This distinction supports more disciplined international benchmarking and directs subsequent evaluation toward expenditure timing and the conversion of resources into effective care.

7. Conclusion and Implications:

Global spending comparisons can mislead policy when national differences are interpreted as returns to additional resources. Examining three funding streams jointly, this analysis shows that strong international gradients contract substantially after accounting for persistent national differences and shared annual conditions. The contribution is an empirical distinction between financing capacity across systems and contemporaneous associations within them. This distinction refines financing transition frameworks by demonstrating that aggregate spending patterns do not establish equivalent annual improvements in population survival. The findings neither identify causal pathways nor justify interpreting negative estimates as evidence that additional resources cause harm. Their practical value lies in improving how decision makers evaluate expenditure evidence. Budget authorities should distinguish international benchmarking from assessments of domestic progress, report uncertainty alongside estimated relationships, and examine whether conclusions depend on expenditure scaling or sample composition. International organizations should assess reporting coverage before treating observed economies as representative of all health systems. Operationally, maintaining consistent definitions, documenting revisions and reviewing unusual observations can strengthen the credibility of comparative assessments. These practices support more defensible allocation decisions and reduce the risk of using imprecise associations to justify spending reductions. The broader social contribution is a disciplined evidential basis for decisions affecting access to care and population wellbeing.

The observational design creates opportunities for more targeted investigation. Nominal expenditure measures invite comparisons using purchasing power and constant prices, while selective coverage motivates analyses with additional reporting sources and explicit missingness models. Annual contemporaneous relationships can be extended through distributed timing specifications that distinguish expenditure responses from subsequent health changes. Linking financing records with service utilization, treatment quality and specific mortality outcomes would permit direct assessment of proposed transmission pathways. Comparisons across institutional settings could then evaluate whether associations vary systematically. Such extensions would clarify the conditions under which additional resources translate into improved survival without assuming that temporal ordering alone establishes causality.

References:

1. Bell, A., Fairbrother, M., & Jones, K. (2019). Fixed and random effects models: Making an informed choice. Quality & Quantity, 53(2), 1051-1074. https://doi.org/10.1007/s11135-018-0802-x
2. Bendavid, E., & Bhattacharya, J. (2014). The relationship of health aid to population health improvements. JAMA Internal Medicine, 174(6), 881-887. https://doi.org/10.1001/jamainternmed.2014.292
3. Cameron, A. C., & Miller, D. L. (2015). A practitioner's guide to cluster-robust inference. Journal of Human Resources, 50(2), 317-372. https://doi.org/10.3368/jhr.50.2.317
4. Carpenter, J. R., & Smuk, M. (2021). Missing data: A statistical framework for practice. Biometrical Journal, 63(5), 915-947. https://doi.org/10.1002/bimj.202000196
5. Cinelli, C., & Hazlett, C. (2020). Making sense of sensitivity: Extending omitted variable bias. Journal of the Royal Statistical Society: Series B, Statistical Methodology, 82(1), 39-67. https://doi.org/10.1111/rssb.12348
6. Fan, V. Y., & Savedoff, W. D. (2014). The health financing transition: A conceptual framework and empirical evidence. Social Science & Medicine, 105, 112-121. https://doi.org/10.1016/j.socscimed.2014.01.014
7. Global Burden of Disease Health Financing Collaborator Network. (2017). Evolution and patterns of global health financing 1995-2014: Development assistance for health, and government, prepaid private, and out-of-pocket health spending in 184 countries. The Lancet, 389(10083), 1981-2004. https://doi.org/10.1016/S0140-6736(17)30874-7
8. Hughes, R. A., Heron, J., Sterne, J. A. C., & Tilling, K. (2019). Accounting for missing data in statistical analyses: Multiple imputation is not always the answer. International Journal of Epidemiology, 48(4), 1294-1304. https://doi.org/10.1093/ije/dyz032
9. Imai, K., & Kim, I. S. (2019). When should we use unit fixed effects regression models for causal inference with longitudinal data? American Journal of Political Science, 63(2), 467-490. https://doi.org/10.1111/ajps.12417

10. Imai, K., & Kim, I. S. (2021). On the use of two-way fixed effects regression models for causal inference with panel data. Political Analysis, 29(3), 405-415. https://doi.org/10.1017/pan.2020.33
11. Jowett, M., Brunal, M. P., Flores, G., & Cylus, J. (2016). Spending targets for health: No magic number. World Health Organization. https://www.who.int/publications/i/item/WHO-HIS-HGF-HFWorkingPaper-16.1
12. Kruk, M. E., Gage, A. D., Joseph, N. T., Danaei, G., García-Saisó, S., & Salomon, J. A. (2018). Mortality due to low-quality health systems in the universal health coverage era: A systematic analysis of amenable deaths in 137 countries. The Lancet, 392(10160), 2203-2212. https://doi.org/10.1016/S0140-6736(18)31668-4
13. Kutzin, J. (2013). Health financing for universal coverage and health system performance: Concepts and implications for policy. Bulletin of the World Health Organization, 91(8), 602-611. https://doi.org/10.2471/BLT.12.113985
14. Lee, K. J., Tilling, K. M., Cornish, R. P., Little, R. J. A., Bell, M. L., Goetghebeur, E., Hogan, J. W., & Carpenter, J. R. (2021). Framework for the treatment and reporting of missing data in observational studies: The Treatment And Reporting of Missing data in Observational Studies framework. Journal of Clinical Epidemiology, 134, 79-88. https://doi.org/10.1016/j.jclinepi.2021.01.008
15. Lu, C., Schneider, M. T., Gubbins, P., Leach-Kemon, K., Jamison, D., & Murray, C. J. L. (2010). Public financing of health in developing countries: A cross-national systematic analysis. The Lancet, 375(9723), 1375-1387. https://doi.org/10.1016/S0140-6736(10)60233-4
16. Madley-Dowd, P., Hughes, R., Tilling, K., & Heron, J. (2019). The proportion of missing data should not be used to guide decisions on multiple imputation. Journal of Clinical Epidemiology, 110, 63-73. https://doi.org/10.1016/j.jclinepi.2019.02.016
17. Moreno-Serra, R., & Smith, P. C. (2012). Does progress towards universal health coverage improve population health? The Lancet, 380(9845), 917-923. https://doi.org/10.1016/S0140-6736(12)61039-3
18. Moreno-Serra, R., & Smith, P. C. (2015). Broader health coverage is good for the nation's health: Evidence from country level panel data. Journal of the Royal Statistical Society: Series A, Statistics in Society, 178(1), 101-124. https://doi.org/10.1111/rssa.12048
19. Organisation for Economic Co-operation and Development, Eurostat, & World Health Organization. (2011). A system of health accounts: 2011 edition. OECD Publishing. https://doi.org/10.1787/9789264116016-en
20. Reeves, A., Gourtsoyannis, Y., Basu, S., McCoy, D., McKee, M., & Stuckler, D. (2015). Financing universal health coverage effects of alternative tax structures on public health systems: Cross-national modelling in 89 low-income and middle-income countries. The Lancet, 386(9990), 274-280. https://doi.org/10.1016/S0140-6736(15)60574-8
21. Seaman, S., Galati, J., Jackson, D., & Carlin, J. (2013). What is meant by "missing at random"? Statistical Science, 28(2), 257-268. https://doi.org/10.1214/13-STS415
22. United Nations, Department of Economic and Social Affairs, Population Division. (2022). World population prospects 2022: Methodology of the United Nations population estimates and projections. https://www.un.org/development/desa/pd/content/wpp-2022-methodology-report
23. World Bank. (2013). World development indicators 2013. https://doi.org/10.1596/978-0-8213-9824-1
24. World Health Organization. (2010). The world health report: Health systems financing: The path to universal coverage. https://www.who.int/publications/i/item/9789241564021
25. World Health Organization. (2023). Global spending on health: Coping with the pandemic. https://www.who.int/publications/i/item/9789240086746