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HEALTH FINANCING STRUCTURES AND OLDER ADULT LONGEVITY: COMPARATIVE EVIDENCE FROM SEX DISAGGREGATED NATIONAL ANNUAL PANELS

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Abstract:

This analysis examines whether international health financing gradients persist within countries when explaining longevity after age 60. An unbalanced panel combines 2,685 complete country and year observations across 193 economies during 2010 to 2024. Separate female and male models include country and year effects, country clustered standard errors and Holm adjustment across six primary tests. Positive pooled expenditure associations reverse after adjustment: a one percentage point higher expenditure share corresponds to 0.065 fewer remaining years for females and 0.050 fewer years for males. Only the female association survives multiplicity adjustment. Government and household financing shares have imprecise baseline estimates, and paired comparisons provide no clear evidence of coefficient differences by sex. Excluding the sparsely observed terminal year leaves expenditure estimates largely unchanged, whereas country specific trends weaken precision. The findings refine health financing transition theory by distinguishing favorable international gradients from conditional national relationships without identifying causal transmission channels. Globally, expenditure ratios should inform benchmarking alongside service delivery and financial protection evidence rather than independently justify budget reallocations.

Key Words: Health Financing; Older Adult Longevity; Life Expectancy; Panel Data; Fixed Effects

1. Introduction:

Health systems face a policy problem that expenditure totals alone cannot resolve: whether a larger financial commitment to health accompanies longer survival among older adults. The scale of that commitment is substantial. The World Health Organization, 2024, reports that global health expenditure reached US$9.8 trillion in 2021, equivalent to 10.3 percent of global gross domestic product. These figures establish the importance of financing decisions, but they do not identify the survival benefits associated with different financing arrangements. For older populations, the question concerns both the resources devoted to healthcare and the distribution of financial responsibility between governments and households. Distinguishing these dimensions matters when national expenditure indicators inform budget priorities and international performance comparisons. Health financing transition theory provides a basis for examining these dimensions separately. Fan and Savedoff, 2014, describe a transition involving rising expenditure per person and declining reliance on direct household payments. Resource expansion and financial pooling are related processes, but neither guarantees the other. Kutzin, 2013, further distinguishes revenue collection, pooling and purchasing as financing functions with different implications for access and financial protection. This analysis therefore separates expenditure intensity, measured by current health expenditure relative to gross domestic product, from financing composition, measured by government and direct household shares of current health expenditure. The distinction prevents a higher expenditure ratio from being interpreted automatically as broader access or stronger protection.

Each financing dimension admits competing interpretations. Greater expenditure intensity may accompany expanded provision, but the ratio can also increase when economic output contracts or treatment needs rise. A larger government share may support collective financing, yet it does not directly measure eligibility, service quality or the effectiveness of purchasing arrangements. Greater reliance on direct household payments may constrain access when care depends on immediately available resources. Morgan and Lee, 2017, document differences in medication nonadherence associated with costs among older adults across eleven developed countries. Their evidence establishes the relevance of financial barriers, but it does not make an aggregate household financing share a direct measure of individual affordability. These distinctions motivate tests of national associations without treating the proposed behavioral pathways as measured mechanisms. The closest empirical literature demonstrates why the relationship requires careful specification. Heijink and colleagues, 2013, associate healthcare spending growth with reductions in avoidable mortality across fourteen western countries, including after adjustment for temporal trends and other characteristics. Their outcome captures mortality considered responsive to timely and effective healthcare rather than remaining life expectancy among older adults. Gallet and Doucouliagos, 2017, show through meta regression that estimated spending relationships depend on outcome definition, the age at which life expectancy is measured and the treatment of spending endogeneity. Together, these studies establish that expenditure and survival cannot be linked through a single transferable coefficient. They leave open whether favorable financing gradients across national observations also characterize changes in longevity within countries after persistent national differences and common annual conditions are accounted for.

Life expectancy at age 60 provides an outcome aligned with this question because it summarizes remaining survival under period mortality conditions after entry into older adulthood. Female and male values are examined separately, preserving differences in survival without assuming that financing responses differ by sex. The measure concerns population mortality rather than individual treatment effectiveness, healthy life expectancy or access to specific services. Financing indicators likewise describe the national health system rather than expenditure directed exclusively toward older people. The analysis consequently addresses the association between national financing conditions and older adult longevity, not the return to an individual

healthcare intervention. This study aims to determine whether expenditure intensity, government financing share and direct household financing share are associated with female and male life expectancy at age 60, and whether pooled patterns persist within countries. The research question is whether international financing gradients provide the same empirical account of longevity as conditional national changes over time. The objectives are to estimate each financing association while holding the other financing measures constant, distinguish pooled relationships from those remaining after country and year adjustment, and assess sensitivity across sex groups and alternative temporal specifications. The dataset combines World Bank World Development Indicators and Gender Statistics in an unbalanced annual panel covering 2010 to 2024. It contains 2,685 complete country and year observations across 193 countries and economies, with paired female and male outcomes. Separate models include country and year effects, country clustered uncertainty and adjustment across the six primary coefficient tests. Temporal restrictions, a balanced sample, country specific trends and consecutive annual differences assess the stability of the estimates.

The completed analysis contributes by showing that pooled financing gradients and conditional national relationships provide different accounts of older adult longevity. Expenditure intensity is positively correlated with both outcomes in pooled observations but negatively associated with them after country and year adjustment. The female baseline association remains distinguishable from zero after adjustment for multiple testing, although country specific trends weaken its precision. Financing composition estimates also change across specifications, preventing a stable directional interpretation. These findings qualify the use of aggregate expenditure indicators as evidence of survival returns rather than establishing that expenditure reduces longevity. Papanicolas and colleagues, 2018, identify prices and administrative costs as contributors to spending differences among wealthy countries, reinforcing the distinction between financial magnitude and the services it purchases. The practical contribution is therefore to separate international benchmarking from evaluation of national change: neither a favorable country ranking nor a negative adjusted coefficient is sufficient evidence for a particular budget or financing reform.

2. Theory, Conceptual Framework and Hypothesis Development:

This analysis draws on health financing transition theory to examine how national expenditure patterns relate to longevity after age 60. The theory distinguishes the resources devoted to health from the arrangements through which those resources are financed. Fan and Savedoff, 2014, describe a transition involving rising health expenditure per person and declining reliance on direct household payments. These processes need not advance together. A country can spend more while maintaining financial barriers, making expenditure intensity and financing composition conceptually distinct predictors of longevity. The framework treats health financing as an institutional arrangement connecting governments, providers and households. Governments mobilize resources, providers allocate services, and households decide whether to seek care under financial constraints. Kutzin, 2013, explains that revenue collection, pooling and purchasing shape financial protection and service access through different mechanisms. Accordingly, this analysis represents financing through three observed measures: current health expenditure as a percentage of gross domestic product, domestic government expenditure as a percentage of current health expenditure, and direct household payments as a percentage of current health expenditure. These indicators enter separately rather than forming an unvalidated composite index.

Older adult longevity is measured by remaining life expectancy at age 60, with female and male values examined separately. The central theoretical proposition is that financing arrangements can support survival by sustaining access to effective care. However, financing is not equivalent to effective coverage. Moreno Serra and Smith, 2012, find that broader coverage generally supports population health while emphasizing institutional conditions and limitations in the evidence. Their findings motivate the financing and longevity relationship without establishing its magnitude or direction for older adults in the available panel. Current health expenditure as a percentage of gross domestic product measures expenditure intensity relative to national economic output. A larger share can support service availability and treatment continuity when additional expenditure purchases effective care. For older populations, sustained financing could therefore correspond to longer remaining life expectancy. The measure nevertheless captures neither expenditure per older person nor the quantity of services received. The competing interpretation is that a higher expenditure share reflects rising prices, greater treatment needs or a contraction in economic output. Longer survival can also increase demand for health services, creating a potential reverse relationship. Expenditure intensity therefore cannot be assigned an unambiguous positive direction from its definition alone. Savedoff and colleagues, 2012, show that transitions toward universal coverage depend on political commitments and institutional development alongside economic resources. This evidence supports distinguishing expenditure intensity from the arrangements that translate spending into access. Because the available measure cannot separate resource expansion from these competing influences, this analysis retains a nondirectional hypothesis.

H1: Current health expenditure as a percentage of gross domestic product is associated with life expectancy at age 60, conditional on financing composition.

Government financing share captures the proportion of current health expenditure financed through domestic government resources. Unlike expenditure intensity, this measure concerns the distribution of financing responsibility. Public financing can distribute expenditure across taxpayers and beneficiaries, reducing dependence on the resources available to an individual household when care is needed. A larger government share may consequently support continuity of care and longer survival. However, the share can rise because government expenditure increases or because other financing sources contract. It also does not directly measure the breadth of entitlement, purchasing effectiveness or the distribution of benefits among older adults. These distinctions prevent government financing share from being interpreted as a complete measure of financial protection. Reeves and colleagues, 2015, associate domestic revenue mobilization with government health spending and coverage, while showing that financing arrangements influence the distribution of benefits. Moreno Serra and Smith, 2015, provide complementary evidence linking broader coverage and pooled financing with population health. These findings support a favorable theoretical expectation, but they do not establish that every increase in government financing share improves older adult longevity. The empirical hypothesis therefore tests the association without treating its expected direction as an established result.

H2: Domestic government expenditure as a percentage of current health expenditure is associated with life expectancy at age 60, conditional on expenditure intensity and direct household financing share.

Direct household financing share measures reliance on payments made by households when obtaining health services. Its theoretical relevance arises from the timing of payment. When payment coincides with illness, households must reconcile treatment needs with immediately available resources. Repeated expenditure can therefore discourage the initiation or continuation of necessary care. This mechanism suggests an adverse relationship with longevity, particularly where older people require continuing treatment. Nevertheless, the aggregate share does not identify which households pay, whether payments purchase necessary services, or whether people forgo care entirely. Low recorded household expenditure can reflect financial protection or restricted access. The relationship must therefore be assessed rather than inferred from the financing share alone. Morgan and Lee, 2017, document differences in medication nonadherence associated with costs among older adults across 11 developed countries. Their findings support the plausibility of financial barriers as a behavioral mechanism, but medication adherence is not measured in the present dataset. This analysis consequently tests the aggregate financing association without claiming to estimate that mechanism.

H3: Direct household payments as a percentage of current health expenditure are associated with life expectancy at age 60, conditional on expenditure intensity and government financing share.

The conceptual framework links each observed financing indicator directly to the same longevity outcome. These links represent conditional associations rather than identified causal effects. Government and household shares use the same expenditure denominator but are not exhaustive complements because other financing sources remain. Their coefficients therefore describe differences relative to the remaining financing composition, rather than a simple exchange between public and household funding. Separate examination of female and male longevity preserves the outcome stratification without treating repeated national financing values as independent exposures.

3. Data:

This analysis establishes data provenance, defines the analytical population and documents the construction of a comparable annual panel. It operationalizes national health financing and longevity after age 60 through observed indicators, with transparent sample selection, missingness assessment and reproducible descriptive calculations.

3.1 Data Sources, Population, and Sample Construction:

The analytical window covers 2010 to 2023. National financing indicators originate from the World Health Organization Global Health Expenditure Database and are distributed through World Bank World Development Indicators. Their accounting interpretation follows the distinction between expenditure on current health services and investment in capital assets established by the Organisation for Economic Cooperation and Development, Eurostat and World Health Organization, 2011. The three-financing series measure current health expenditure relative to gross domestic product, domestic government expenditure relative to current health expenditure, and direct household expenditure relative to current health expenditure. Female and male life expectancy at age 60 come from World Bank Gender Statistics. The workbook attributes these series to United Nations World Population Prospects 2022. This release contains population estimates and projections, requiring a distinction between the annual reference period and the information used to construct the series. The workbook does not provide observation specific flags distinguishing estimated from projected longevity values. Accordingly, values for 2022 and 2023 are not treated as independently verified mortality realizations. United Nations Department of Economic and Social Affairs, Population Division, 2022, provides the underlying demographic release documentation.

World Development Indicators is accessed through World Bank API source 2, and Gender Statistics through API source 14. Exact extraction timestamps, API update dates and retrieval queries remain recorded in the supplied workbook Sources sheet. These identify the downloaded snapshots rather than an archived information set available at each historical observation date. The workbook records World Bank attribution requirements and a Creative Commons Attribution licence, subject to original source conditions. The target population comprises national health systems and the older populations whose survival conditions they support. The accessible frame contains 217 World Bank countries and economies after the exclusion of regional aggregates. These are statistical reporting units rather than a count of sovereign states. Selection uses all available eligible units rather than a probability sample. This international coverage supports comparison of financing arrangements, but expenditure represents the entire national health system rather than resources devoted specifically to older people. The World Health Organization, 2023, documents the distinction between financing sources and aggregate expenditure within international health spending statistics.

The primary unit is the country and year. Female and male longevity observations form paired outcome strata within each unit. Financing indicators are annual ratios of expenditure flows, while life expectancy is a period demographic measure derived from mortality schedules. Neither measure represents an individual treatment exposure. Distinguishing expenditure intensity from financing composition follows the conceptual separation developed by Fan and Savedoff, 2014, while retaining the institutional interpretation of financing functions explained by Kutzin, 2013. The calendar restriction to 2010 through 2023 was applied for the present manuscript before calculating the reported descriptive results. Complete records require all three financing indicators and both longevity measures. Table 1 separates economies excluded entirely from incomplete observations within retained economies.

Table 1: Sample construction

Stage	Economies	Country and Year Observations	Reason or Rule
Initial eligible frame	217	3,038	Fourteen annual observations per economy
Entirely unavailable financing histories excluded	24 removed	336 removed	No complete financing observations within the analytical window
Partial financing gaps excluded	6 affected	24 removed	Incomplete annual records within economies retained in other years
Complete analytical sample	193 retained	2,678 retained	Three financing measures and both longevity measures available

Stage	Economies	Country and Year Observations	Reason or Rule
Female outcome stratum	193	2,678	One female longevity observation per retained country and year
Male outcome stratum	193	2,678	One male longevity observation per retained country and year
Combined sex specific representation	193	5,356 sex specific rows	Two outcome strata sharing each national financing observation

The panel is unbalanced. Of the 193 retained economies, 187 contribute all fourteen years. The remaining six contribute between six and thirteen years. Annual coverage increases from 188 economies in 2010 to 193 during 2018 through 2021, before reaching 192 in 2022 and 2023. The combined representation therefore contains 5,356 outcome rows but only 2,678 distinct national financing observations.

3.2 Data Integration, Cleaning, and Quality Assurance:

The workbook aligns indicators through the World Bank economy identifier and annual reference year. The audit reconstructed complete records from the raw matched extract and verified that they reproduced the corresponding analysis rows within the selected window. Country names remain descriptive labels rather than merge keys. Explicit identification of linkage fields and retained records follows the transparency principles described by Gilbert and colleagues, 2018. No duplicate country and year keys occur in the raw extract, and no duplicate country, year and sex keys occur in the analytical sample. The two sex rows are intentional paired observations rather than duplicate financing records. All five numerical series are obtained through the same dissemination provider, so no competing source priority rule is required. The audit documents selection and reconstruction without claiming independent validation of the original national submissions. This distinction follows the reporting emphasis of Benchimol and colleagues, 2015, on making data selection and processing visible. Within the 3,038 eligible records, each financing indicator has 360 missing values. Female and male longevity each have 28 missing values. All missing longevity records fall within observations already excluded for unavailable financing, producing no additional loss after financing completeness is imposed. Missing observations are retained as blank values in the raw extract. No zero substitution, interpolation or imputation is applied. Hughes and colleagues, 2019, distinguish the assumptions supporting complete observation analysis from those required for imputation; completeness alone does not establish that selection is unbiased.

Missingness is concentrated across economies rather than distributed uniformly. Twenty-four economies lack financing observations throughout the window, six have partial gaps, and 187 have no incomplete records. Annual incomplete counts decline from 29 in 2010 to 24 during 2018 through 2021, before increasing to 25 in 2022 and 2023. Among excluded records with available longevity values, mean female longevity is 23.77 years and mean male longevity is 19.86 years, compared with 20.91 and 17.84 years in retained records. These descriptive differences show that exclusions change sample composition. They do not identify the missingness mechanism, consistent with the distinction emphasized by Madley Dowd and colleagues, 2019. Quality checks confirmed nonnegative financing values, government and household shares within zero to one hundred, and positive remaining life expectancy. The combined government and household share does not exceed one hundred beyond a rounding tolerance of 0.00001 percentage points. Extreme observations were retained because magnitude alone does not establish error. No trimming or winsorization was performed. This treatment follows the distinction between valid extreme values and erroneous records developed by Aguinis and colleagues, 2013. The financing variables already express expenditure as percentages, and longevity is measured in years. Annual reference years are matched directly. The available fields do not permit separate verification of national fiscal calendar adjustments or reconstruction of historical publication delays. The analysis therefore uses the revised historical series contained in the supplied workbook rather than a contemporaneous forecasting information set.

3.3 Variable Measurement, Construction, and Validation:

Life expectancy at age 60 represents expected remaining years under the mortality conditions underlying a period life table. It is not the observed remaining lifetime of a cohort. Female and male values retain their original units and remain separate outcome strata. The distinction between period longevity and the distribution of individual lifetimes is consistent with Aburto and colleagues, 2020. Current health expenditure relative to gross domestic product represents national expenditure intensity. Government and direct household shares represent financing composition. None is interpreted as effective service coverage or financial protection itself. Moreno Serra and Smith, 2012, distinguish expanded coverage from expenditure alone, while their subsequent panel analysis demonstrates the importance of specifying the financing dimension associated with population health. These distinctions guide interpretation without importing their estimates into the present dataset.

Table 2: Variable dictionary

Variable or Indicator	Analytical Role	Definition and Construction	Source and Identifier	Unit and Frequency	Transformation and Direction	Missing Value Rule	Coverage and Limitation
Current health expenditure	Predictor	Current health expenditure divided by gross domestic product, multiplied by one hundred	World Bank World Development Indicators	Percentage, annual	Original level; higher values indicate greater expenditure intensity	Exclude incomplete country and year records	2,678 retained observations; not expenditure per older person
Government financing share	Predictor	Domestic government health expenditure divided by current health expenditure, multiplied by one hundred	World Bank World Development Indicators	Percentage, annual	Original level; higher values indicate a larger government financing contribution	Same complete record rule	2,678 retained observations; does not measure entitlement or purchasing effectiveness
Direct household financing share	Predictor	Direct household health expenditure divided by current health expenditure,	World Bank World Development	Percentage, annual	Original level; higher values indicate greater reliance on direct	Same complete record rule	2,678 retained observations; does not measure household

Variable or Indicator	Analytical Role	Definition and Construction	Source and Identifier	Unit and Frequency	Transformation and Direction	Missing Value Rule	Coverage and Limitation
		multiplied by one hundred	Indicators		household payments		income burden
Female life expectancy at age 60	Outcome stratum	Provider supplied remaining life expectancy at exact age 60 for females	World Bank Gender Statistics	Years, annual	Original level; higher values indicate longer remaining life expectancy	Require an available female value	2,678 retained observations; period estimate with projection concerns for recent years
Male life expectancy at age 60	Outcome stratum	Provider supplied remaining life expectancy at exact age 60 for males	World Bank Gender Statistics	Years, annual	Original level; higher values indicate longer remaining life expectancy	Require an available male value	2,678 retained observations; same demographic limitation
Economy identifier	Panel identifier	Provider supplied economy code	World Bank country metadata	Categorical, annual	No transformation	Require a valid identifier	193 retained economies
Year	Temporal identifier	Annual reference year	Provider supplied observation date	Calendar year	Restricted to 2010 through 2023	Require a valid year	Fourteen possible observations per economy
Sex	Stratification identifier	Female or male outcome classification	Gender Statistics series designation	Categorical, annual	Separate outcome strata	Require both strata for each retained country and year	Financing values repeat across strata

Direct household expenditure is a health financing share rather than a measure of the proportion of household income spent on health. It therefore cannot identify catastrophic expenditure or individual affordability. Morgan and Lee, 2017, show that costs can affect access to medicines among older adults, but that behavioral mechanism is not directly measured here. All indicators retain their original numerical precision for calculation. Displayed statistics are rounded to two decimal places. Financing variables are expressed on a zero to one hundred percentage scale rather than a zero to one ratio scale. A difference of one unit therefore represents one percentage point. No logarithms, growth rates, interactions, weights or composite indices are constructed.

Table 3: Descriptive statistics for complete observations

Indicator	Valid Observations	Mean	Standard Deviation	Median	Minimum	Maximum
Current health expenditure as percentage of gross domestic product	2,678	6.52	2.96	6.06	1.33	27.09
Government share of current health expenditure	2,678	51.39	22.23	53.88	0.79	95.03
Direct household share of current health expenditure	2,678	31.83	19.12	29.22	0.04	87.90
Female life expectancy at age 60	2,678	20.91	3.53	20.57	7.71	29.75
Male life expectancy at age 60	2,678	17.84	3.05	16.91	5.58	26.03

Financing statistics use distinct country and year records, preventing the paired outcome representation from doubling the financing sample. Pearson correlations between financing indicators are 0.227 for expenditure intensity and government share, negative 0.313 for expenditure intensity and household share, and negative 0.711 for government and household shares. These describe linear covariation rather than redundancy or causality. Their interpretation follows Schober and colleagues, 2018.

3.4 Analytical Framework, Identification, and Reproducibility:

The completed analysis is descriptive. It characterizes financing distributions, sex specific longevity, sample coverage and covariation among financing indicators. National observations receive equal weight, so the summaries describe the distribution across available country and year records rather than the experience of a population weighted global individual. The paired structure preserves the distinction between shared national financing conditions and sex specific outcomes. The data permit examination of financing and longevity associations, but the reported audit does not estimate a causal effect. National income, morbidity, service quality and institutional differences are not measured as controls in the supplied analytical table. Changes in health needs can also affect financing, making the direction of influence uncertain. Hernán, 2018, emphasizes that causal interpretation requires an explicit identification argument rather than a change in terminology. The accompanying reproducibility package contains the filtered data, variable dictionary, annual and economy specific missingness summaries, descriptive statistics, financing correlations and executable audit code. The code verifies unique identifiers, checks numerical bounds and reconstructs the analytical sample from the raw matched extract. An input file checksum identifies the exact workbook used. These materials connect each reported count and statistic to an executable procedure, following Sandve and colleagues, 2013.

4. Methods:

4.1 Research Design and Analytical Identification:

This analysis uses an observational annual panel to estimate conditional associations between national health financing and remaining life expectancy at age 60 during 2010 to 2024. The unit of analysis is the country and year, with female and male outcomes estimated separately. The estimands are longevity differences associated with one percentage point differences in each financing indicator, conditional on the other indicators, persistent country characteristics and common annual conditions. Country effects remove persistent national differences, while year effects remove annual movements shared across the sample. Consequently, the principal estimates use financing variation remaining within countries after both adjustments. Pooled comparisons are retained as descriptive benchmarks rather than substitutes for this estimand. This separation follows the distinction between within country and between country relationships discussed by Bell and colleagues, 2019. The design does not identify causal effects. Financing can respond to changing health needs, while national economic conditions can affect both expenditure ratios and survival. Country and year effects do not remove all changing national influences. The coefficients

therefore describe conditional linear associations in the retained observations, without assuming that financing changes constitute externally assigned interventions. The sample construction table and variable dictionary establish eligibility and measurement definitions. For the full observation window, each primary outcome model contains 2,685 country and year observations across 193 countries and economies. Separate estimation preserves the paired outcome structure without treating repeated national financing values as independent exposures. All observations receive equal weight; the estimand therefore concerns available national records rather than a population weighted global individual.

4.2 Model Specification and Measurement Alignment:

The baseline specification is Equation 1.

$$L_{it}^{s} = \alpha_i^s + \lambda_t^s + \beta_1^s E_{it} + \beta_2^s G_{it} + \beta_3^s O_{it} + \varepsilon_{it}^s$$

Here, L_{it}^{s} denotes remaining life expectancy at age 60 in country i, year t and sex stratum s. The stratum is female or male. E_{it} is current health expenditure as a percentage of gross domestic product, G_{it} is domestic government expenditure as a percentage of current health expenditure, and O_{it} is direct household expenditure as a percentage of current health expenditure. The terms α_i^s and λ_t^s represent country and year effects. Each β_j^s is a conditional slope, and ε_{it}^s is the remaining disturbance. All explanatory variables and outcomes refer to the same annual reference year. Financing indicators retain their original percentage scales, and longevity retains its unit of years. No logarithmic transformation, standardization, composite index or population weighting is applied. Each slope therefore expresses longevity years per percentage point of the corresponding financing measure. Government and household financing shares do not exhaust current health expenditure. Their coefficients consequently describe conditional compositional differences involving the remaining financing sources rather than a complete substitution between these two categories. Expenditure intensity likewise measures a ratio to economic output rather than expenditure per older person.

The primary specification contains no additional controls, interactions, mediators or lagged predictors. Sex defines separate outcome strata rather than a moderator. The three financing indicators retain estimable variation after country and year adjustment, as verified through the rank of the residualized explanatory matrix. A supplementary paired analysis defines the longevity difference in Equation 2.

$$D_{it} = L_{it}^{F} - L_{it}^{M}$$

Here, D_{it} is female minus male remaining life expectancy, while F and M denote the female and male strata. Equation 1 is then estimated with D_{it} as the outcome. Because both strata share identical observations and explanatory variables, these slopes equal the differences between their separately estimated financing coefficients. This procedure assesses coefficient differences directly rather than inferring them from differences in statistical significance.

4.3 Estimation, Statistical Inference and Diagnostic Assessment:

Coefficients are estimated by ordinary least squares after projecting the outcome and explanatory variables onto the complement of the country and year indicator space. Pivoted QR decomposition identifies the fixed effect space, and least squares estimates the slopes from the residualized variables. The baseline implementation includes a complete set of country indicators without a separate intercept and omits the first-year indicator. Country clustered covariance is calculated using Equation 3.

$$\widehat{V} = \frac{C}{C-1}\frac{N-1}{N-K} A^{-1}\left[\sum_{i=1}^{C} q_i\, q_i^{'}\right] A^{-1}, \qquad A = \widetilde{X}'\widetilde{X}, \qquad q_i = \widetilde{X}_i'\hat{\varepsilon}_i$$

Here, $\widehat{V}$ is the estimated covariance matrix of the financing slopes, C is the number of country clusters, N is the number of observations, and K is the full model rank, including absorbed effects. The matrix $\widetilde{X}$ contains explanatory variables residualized against the fixed effects, while $\widetilde{X}_i$ contains its observations for country i. The vector $\hat{\varepsilon}_i$ contains that country's fitted model residuals. Primes denote transposition. The baseline models have 193 clusters and a full rank of 210. Two-sided tests and 95 percent confidence intervals use a student t distribution with 192 degrees of freedom. Equation 3 permits heteroskedasticity and dependence within countries, following the principles discussed by Cameron and Miller, 2015. It does not address every possible dependence pattern across countries; interpretation remains conditional on sufficiently independent country clusters after annual adjustment.

The six primary tests comprise three financing slopes for each sex. Holm adjustment is applied jointly across this family by ordering the unadjusted probabilities, applying successive multiplicity factors and enforcing monotonic adjusted probabilities. An adjusted probability below 0.05 provides the stated criterion for evidence against a zero-baseline association. Reported confidence intervals are marginal rather than simultaneous. Paired difference tests and sensitivity estimates remain supplementary and are not included in this primary family. Diagnostic assessment uses variance inflation factors calculated from the residualized predictor correlation matrix, partial coefficients of determination after fixed effect removal, and descriptive correlations between residuals in consecutive years within countries. These quantities assess predictor overlap, remaining explanatory contribution and residual persistence. Residual correlations are not interpreted as formal independence tests. Coefficient magnitude, uncertainty and specification sensitivity guide interpretation rather than threshold compliance alone, consistent with Wasserstein and colleagues, 2019. Numerical verification independently estimated the baseline models using an explicit full indicator design. The resulting slopes and clustered standard errors reproduced the residualized implementation within numerical precision.

4.4 Sensitivity Analysis, Processing and Reproducibility:

Processing begins by checking unique country, year and sex identifiers and verifying that female and male observations share the same country and year keys. The analytical representation then retains one financing record per country and year alongside both outcomes. Complete observation selection follows the documented data rules. No imputation, interpolation, zero replacement, trimming or winsorization is applied. Sensitivity checks address distinct threats. Excluding 2024 assesses reliance on a terminal year with sparse coverage and produces 2,678 observations per sex across 193 countries. Restricting the window to 2010 through 2021 assesses sensitivity to potentially projected longevity values and retains 2,294 observations per sex across 193 countries. A balanced panel for 2010 through 2023 contains 2,618 observations per sex across 187 countries, allowing assessment of incomplete national histories. A further specification adds country specific linear trends to Equation 1 while retaining country

and year effects. Its sample remains identical to the baseline sample, isolating the consequence of the trend specification. One redundant trend is omitted because common linear time movements are already represented by the year indicators.

The first difference analysis subtracts the preceding annual observation within each country for the outcome and all three financing indicators. Only consecutive years are retained, producing 2,492 observations per sex across 193 countries. These models include annual indicators and country clustered inference. The transformation removes persistent national levels but changes the estimand to the association between annual changes. These sensitivity specifications were selected before coefficient inspection in the estimation run but were not preregistered. Additional exploratory analyses, introduced after inspecting the main results and observed ranges, restrict observations to 2010 through 2019 and exclude Tuvalu, Afghanistan, the Central African Republic, South Sudan and Lesotho separately. The earlier window contains 1,908 observations per sex across 193 countries. Each individual country exclusion leaves 192 countries. These exclusions assess sensitivity to selected extreme observations and do not classify them as data errors. Comparisons consider changes in direction, magnitude and uncertainty. Window restrictions, balancing, differencing and country exclusions change the analytical sample, whereas adding country trends changes the specification on the same sample. None of these checks establishes causal identification or removes all selection and measurement concerns. The implementation uses Python 3.12.14, pandas 2.2.3, NumPy 2.3.5, SciPy 1.17.0 and openpyxl 3.1.5 for workbook reading. Estimation is deterministic and requires no random seed. The replication package contains the estimation script, analytical data, descriptive outputs, coefficient estimates, diagnostic quantities, analysis notes and an input workbook checksum. This documentation connects the reported results to executable procedures, following Sandve and colleagues, 2013. The methodological contribution lies in the consistent comparison of pooled, conditional and paired relationships, rather than a new estimator.

5. Findings:

This analysis examines how expenditure intensity and financing composition relate to female and male life expectancy at age 60 across countries during 2010 to 2024.The findings distinguish pooled associations from changes within countries after accounting for common annual conditions. Hypothesis assessments combine coefficient estimates, uncertainty, adjustment for multiple testing and sensitivity to alternative specifications. The analytical sample comprises 2,685 complete country and year observations across 193 countries and economies, represented by 5,370 paired female and male outcome records. All three financing indicators and both longevity measures are available for each retained country and year. Financing summaries use the 2,685 distinct national observations rather than counting shared financing values twice. The panel is unbalanced: seven economies contribute fifteen years, 180 contribute fourteen years, and six contribute between six and thirteen years. Only seven economies have complete observations in 2024, making sensitivity to the terminal year necessary.

Table 4: Distribution of financing indicators and longevity

Indicator	Mean	Standard Deviation	Median	Minimum	Maximum
Current health expenditure as percentage of gross domestic product	6.53	2.96	6.06	1.33	27.09
Government share of current health expenditure	51.44	22.23	53.95	0.79	95.03
Direct household share of current health expenditure	31.80	19.12	29.17	0.04	87.90
Female life expectancy at age 60, years	20.92	3.54	20.59	7.71	29.75
Male life expectancy at age 60, years	17.84	3.05	16.91	5.58	26.03
Female minus male longevity difference, years	3.08	1.30	3.05	0.32	11.40

Financing composition varies substantially across the sample. Government financing ranges from 0.79 to 95.03 percent of current health expenditure, while direct household financing ranges from 0.04 to 87.90 percent. Female longevity exceeds male longevity in every retained country and year, with an average difference of 3.08 years. This persistent ordering establishes a descriptive sex difference but does not establish that financing explains it. Pooled correlations indicate that longer remaining life expectancy accompanies higher expenditure intensity, greater government financing and lower reliance on direct household payments. Government financing has the largest unadjusted correlation with both outcomes. These patterns are consistent with the broad financing transitions described by Fan and Savedoff, 2014, but combine differences between countries with changes over time. They therefore cannot establish whether a change in financing within a country accompanies improved longevity.

Table 5: Pooled correlations between financing indicators and longevity

Financing Indicator	Female Longevity	Male Longevity
Current health expenditure as percentage of gross domestic product	0.305	0.239
Government financing share	0.645	0.561
Direct household financing share	−0.357	−0.321

The main models enter all three financing indicators jointly and include country and year effects. Country effects absorb persistent differences between economies, while year effects absorb conditions common to the sample in each year. The coefficients therefore describe financing variation within countries after adjustment for common annual movements. This distinction between pooled and within country relationships follows the interpretation developed by Bell and colleagues, 2019. All predictors retain their percentage scales, so each coefficient represents the longevity difference associated with one percentage point in the relevant financing indicator. Standard errors are clustered across 193 countries, allowing heteroskedasticity and dependence within each country. Inference uses a finite sample correction and a student t distribution with 192 degrees of freedom. This approach follows the principles discussed by Cameron and Miller, 2015. The six primary coefficient tests are additionally assessed using Holm adjustment, with an adjusted probability below 0.05 indicating evidence against the corresponding zero association. Confidence intervals remain marginal rather than simultaneous.

Table 6: Financing associations with life expectancy at age 60

Outcome	Predictor	Coefficient	Clustered Standard Error	95 Percent Confidence Interval	Unadjusted p Value	Holm Adjusted p Value
Female	Expenditure intensity	−0.0651	0.0233	−0.1110 to −0.0191	0.0058	0.0345
Female	Government financing share	−0.0044	0.0036	−0.0114 to 0.0026	0.2212	0.8789
Female	Direct household financing share	0.0026	0.0038	−0.0049 to 0.0102	0.4934	0.8789
Male	Expenditure intensity	−0.0499	0.0242	−0.0977 to −0.0021	0.0409	0.2046
Male	Government financing share	−0.0041	0.0033	−0.0107 to 0.0025	0.2197	0.8789
Male	Direct household financing share	0.0041	0.0038	−0.0035 to 0.0117	0.2841	0.8789

Expenditure intensity has a negative conditional association with both longevity outcomes, reversing its positive pooled correlation. For females, a one percentage point higher expenditure share corresponds to 0.065 fewer remaining years, approximately 24 days, with a confidence interval ranging from approximately 7 to 41 fewer days. The association remains distinguishable from zero after adjustment across the six primary tests. For males, the corresponding estimate is approximately 18 fewer days, but its adjusted probability is 0.2046. H1 therefore receives baseline support for female longevity, while the male result does not meet the adjusted evidential criterion. The negative coefficient does not establish that additional health expenditure reduces survival. Expenditure intensity is a ratio rather than a measure of additional services received by older adults. Its conditional association cannot separate changes in expenditure from changes in gross domestic product or health needs. The empirical result is a reversal between pooled and within country patterns, not an identified adverse effect of spending.

Government financing share has a small negative estimate in both main models, with confidence intervals spanning zero. For females, a ten-percentage point difference corresponds to an estimated longevity difference of −0.044 years, with a confidence interval from −0.114 to 0.026 years. The male estimate is similarly imprecise. H2 is not supported by the baseline models. These results do not establish that government financing is ineffective; the observed share does not directly measure entitlement, purchasing arrangements or service access. Kutzin, 2013, distinguishes these financing functions from aggregate expenditure composition. Direct household financing share has positive conditional estimates despite its negative pooled correlations. Both main confidence intervals include zero, and the adjusted probabilities provide no evidence of a distinct association. For females, a ten-percentage point difference corresponds to 0.026 additional years, with a confidence interval from −0.049 to 0.102 years. H3 is therefore not supported by the baseline estimates. The direction of these imprecise coefficients does not establish a longevity benefit from household payments.

The contrast between pooled and adjusted estimates limits what can be inferred from international financing gradients. Economies with larger government shares tend to exhibit higher longevity levels, but changes in those shares do not reproduce the same positive relationship in the baseline panel models. This finding concerns a different outcome and estimand from the broader coverage relationships examined by Moreno Serra and Smith, 2015. It qualifies the interpretation of aggregate financing indicators without contradicting evidence concerning other dimensions of coverage. The financing indicators explain 2.26 percent of female longevity variation and 1.31 percent of male longevity variation remaining after country and year effects are removed. These partial coefficients of determination indicate limited explanatory contribution within the adjusted models. Variance inflation factors range from 1.03 to 1.46 after adjustment for the fixed effects. Predictor overlap therefore does not produce severe numerical inflation of baseline coefficient uncertainty, although government and household shares remain substantively related financing components. Sensitivity estimates show that the expenditure association depends more on temporal specification than on the inclusion of the sparsely observed terminal year. Removing 2024 changes the female coefficient from −0.0651 to −0.0654 and the male coefficient from −0.0499 to −0.0498. Excluding 2022 through 2024, addressing concerns about potentially projected longevity values, preserves the negative estimates. However, country specific trends and the exploratory restriction to observations before 2020 produce wider intervals spanning zero.

Table 7: Sensitivity of the expenditure intensity association

Specification	Observations Per Sex	Countries	Female Coefficient	Female 95 Percent Interval	Male Coefficient	Male 95 Percent Interval
Main model, 2010 to 2024	2,685	193	−0.0651	−0.1110 to −0.0191	−0.0499	−0.0977 to −0.0021
Excluding 2024	2,678	193	−0.0654	−0.1114 to −0.0193	−0.0498	−0.0975 to −0.0022
Restricting observations to 2010 through 2021	2,294	193	−0.0704	−0.1237 to −0.0171	−0.0594	−0.1165 to −0.0024
Balanced panel, 2010 to 2023	2,618	187	−0.0483	−0.0827 to −0.0138	−0.0316	−0.0683 to 0.0051
Country specific linear trends added	2,685	193	−0.0456	−0.0922 to 0.0011	−0.0413	−0.0937 to 0.0112
Consecutive annual first differences	2,492	193	−0.0498	−0.0955 to −0.0042	−0.0466	−0.0964 to 0.0031

Specification	Observations Per Sex	Countries	Female Coefficient	Female 95 Percent Interval	Male Coefficient	Male 95 Percent Interval
Exploratory restriction to 2010 through 2019	1,908	193	−0.0418	−0.0957 to 0.0121	−0.0287	−0.0850 to 0.0276

Financing composition estimates are also specification sensitive. Adding country specific trends produces negative government financing coefficients of −0.0084 for females and −0.0081 for males, with confidence intervals excluding zero. The first difference model produces a negative female government coefficient of −0.0077, while the male interval includes zero. Household financing coefficients become negative under both specifications, but their intervals continue to span zero. These changes prevent a stable directional interpretation of financing composition across models. Exploratory exclusions assessed sensitivity to economies containing extreme financing or longevity observations. Removing Tuvalu, Afghanistan, the Central African Republic, South Sudan or Lesotho separately leaves the female expenditure coefficient negative, ranging from −0.0721 to −0.0484. Each corresponding marginal confidence interval excludes zero. Male coefficients remain negative but are less consistently distinguishable from zero. These checks indicate that the female baseline association is not attributable solely to any one of these five economies; they do not remove the temporal sensitivity shown in Table 7.

A paired analysis of the female minus male longevity difference provides no clear evidence that financing coefficients differ by sex. The expenditure coefficient for the longevity difference is −0.0152 years per percentage point, with a confidence interval from −0.0348 to 0.0045. Government and household financing coefficients likewise have intervals spanning zero. Stronger evidence within the female model therefore does not establish a stronger financing relationship for females. Taken together, the evidence supports a conditional baseline association between expenditure intensity and female longevity, but not a uniformly stable relationship across temporal specifications. H2 and H3 lack consistent support in the main models. The central empirical distinction is that favorable pooled financing gradients do not translate directly into favorable within country associations. Interpretation consequently rests on coefficient magnitude, uncertainty and sensitivity rather than a binary declaration that financing does or does not matter, consistent with Wasserstein and colleagues, 2019.

6. Discussion:

Higher health spending and longer lives do not form the same relationship across countries as they do within countries over time. Tables 5 and 6 expose this distinction: expenditure intensity has a positive pooled correlation with longevity but a negative association after country and year effects are included. The female estimate remains distinguishable from zero after adjustment for multiple testing, although its sensitivity prevents a general adverse interpretation. The contribution is the separation of international financing gradients from conditional national changes in longevity after age 60. Gallet and Doucouliagos, 2017, demonstrate that spending estimates depend on outcome definition, age and model specification. This analysis adds a specific qualification: favorable expenditure gradients across national observations cannot be interpreted directly as evidence that increases in expenditure relative to economic output accompany improved older adult survival. The financing composition results further distinguish the source of expenditure from its association with longevity. Government financing has the strongest pooled correlation with both outcomes in Table 5, yet its conditional estimates in Table 6 are small and imprecise. Direct household financing exhibits the opposite change in sign, moving from negative pooled correlations to imprecise positive conditional coefficients. These contrasts show that financing shares do not retain a stable empirical meaning across analytical comparisons. They do not identify transmission pathways through access, treatment continuity or purchasing effectiveness. Reibling and colleagues, 2019, distinguish healthcare systems through combinations of institutional characteristics rather than financing shares alone. The present evidence sharpens that distinction by showing that national financing composition cannot substitute for a direct assessment of how health systems organize and deliver care.

Temporal specification changes the strength of the expenditure relationship more than the inclusion of the sparsely observed terminal year. Table 7 shows that excluding 2024 leaves the baseline coefficients almost unchanged, whereas adding country specific trends reduces their magnitude and produces confidence intervals spanning zero. The exploratory restriction to observations before 2020 also weakens precision. This pattern locates the principal interpretive challenge in separating financing movements from evolving national conditions, rather than attributing the result to the final observation year. Cylus and colleagues, 2012, show that economic downturns alter government health expenditure growth in European countries. Their evidence makes macroeconomic conditions relevant to interpretation, but the current estimates do not identify an economic crisis mechanism. The theoretical implication is narrower: expenditure ratios should not be treated as autonomous inputs whose relationship with survival remains constant across temporal specifications. The paired outcomes also separate persistent sex differences in longevity from evidence of different financing responses. Table 4 records higher female longevity in every retained country and year, but the paired coefficient comparisons do not establish that financing associations differ between females and males. Stronger baseline evidence for females therefore cannot support a sex specific allocation recommendation. International comparison requires similar care. Heijink and colleagues, 2013, associate healthcare spending growth with reductions in avoidable mortality across fourteen western countries, including after adjustment for temporal trends. The negative expenditure intensity estimates in Table 6 concern a different spending measure, outcome and geographical population. Their divergence narrows the transferability of conclusions across measures rather than demonstrating that spending benefits disappear internationally. This analysis consequently identifies outcome and specification dependence as substantive features of comparative health financing research.

For decision makers, the evidence changes how national financing performance should be interpreted rather than establishing a preferred spending level. Tables 6 and 7 provide no basis for reducing expenditure because its adjusted coefficient is negative, increasing household payment obligations because their baseline coefficients are positive, or ranking financing mechanisms by causal effectiveness. Papanicolas and colleagues, 2018, identify prices and administrative costs as contributors to expenditure differences among wealthy countries, illustrating why expenditure magnitude does not represent a uniform quantity of care. The practical implication is to assess expenditure intensity alongside actual service delivery and financial protection, while keeping international rankings distinct from evaluations of national change. Across the 193 reporting economies, the contribution

is a demonstrated boundary on aggregate financing inference: pooled associations, conditional national relationships and sex differences answer different questions and should not be combined into a single claim about the survival return to health spending

7. Conclusion and Implications:

International spending comparisons can mislead when national rankings are interpreted as evidence of what policy changes will achieve. This analysis shows that favorable international financing gradients do not translate consistently into favorable relationships within countries over time. Examining resource commitment and the distribution of payment responsibility together reveals that their associations with survival depend on the comparison and temporal specification. The central contribution is this empirical separation between pooled patterns and conditional national relationships. It refines health financing transition theory by showing that aggregate financial indicators cannot independently establish progress toward longer lives. The evidence supports neither treating greater expenditure as inherently harmful nor interpreting imprecise financing estimates as proof of institutional irrelevance. For decision makers, the implication is to distinguish benchmarking from policy evaluation before reallocating resources. Budget assessments should connect financial commitments with service delivery, population needs and protection against financial hardship rather than relying on expenditure ratios alone. Operationally, reporting systems should distinguish spending changes from economic denominator movements and compare outcomes across consistent observation windows. These practices can improve the evidence supporting allocation decisions without claiming benefits that the analysis has not identified. Their international relevance lies in preventing misleading comparisons from becoming prescriptions for older populations.

The observational panel provides a foundation for stronger identification rather than a causal estimate. National aggregates cannot resolve individual access, treatment continuity or the services received by older adults. Linking expenditure records with service coverage and household data would permit direct examination of these pathways. Replacing potentially projected longevity observations with verified mortality estimates would strengthen temporal interpretation. Future analyses should examine delayed relationships, institutional differences and policy changes using designs suited to their identification assumptions. Such extensions could establish when the observed associations reflect effective provision, changing needs or economic conditions, while testing their transferability across health systems.

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