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INCOME, POPULATION AGEING, AND URBANISATION AS PREDICTORS OF NATIONAL HEALTH EXPENDITURE ACROSS GLOBAL COUNTRY PANELS

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Abstract:

This analysis examines whether income, population ageing, and urbanisation explain national health expenditure beyond their pooled international associations. World Development Indicators provide 2,672 complete annual observations across 192 economies from 2010 to 2024. Pooled rank correlations are compared with logarithmic expenditure regressions incorporating economy and year effects, economy clustered inference, and coverage sensitivity checks. Income exhibits a positive expenditure elasticity of 0.686, with a 95 percent confidence interval from 0.557 to 0.815. A 10 percent income increase corresponds to approximately 6.76 percent higher nominal expenditure. Ageing and urbanisation display positive pooled correlations but imprecise conditional estimates under baseline inference. The income association persists across balanced coverage and sequential economy exclusions, whereas urbanisation inference changes under an alternative covariance calculation. These results support a resource constraint interpretation without identifying causal transmission mechanisms. The contribution distinguishes international expenditure rankings from conditional relationships and inferential stability. Globally, the evidence supports expenditure benchmarking against economic resources while cautioning against automatic budget adjustments based solely on demographic or settlement composition.

Key Words: Health Expenditure; Income Elasticity; Population Ageing; Urbanisation; Panel Data.

1. Introduction:

National health expenditure reflects the resources available to finance care as well as the needs that healthcare systems confront. These influences are difficult to distinguish in international comparisons because richer economies often have older and more urban populations. A positive relationship between expenditure and demographic composition may therefore combine differences in economic resources, persistent national characteristics, and changes within economies. Distinguishing these relationships matters for expenditure planning: an indicator that explains international spending rankings may provide limited guidance about how spending changes as an individual economy develops. Income provides a starting point for this distinction. Greater economic resources can relax household and collective financing constraints, allowing additional healthcare consumption. However, expenditure need not increase proportionately with income. Baltagi and colleagues, 2017, identify an aggregate necessity relationship in an international panel while documenting variation across geographical and income groups. Vargas Bustamante and Shimoga, 2018, further show that comparisons between middle income and high income economies depend on sample construction and specification. Together, these findings establish income as a relevant predictor while challenging the assumption that a single relationship transfers unchanged across analytical settings.

The interpretation also depends on research design. Acemoglu, Finkelstein, and Notowidigdo, 2013, use income variation generated by oil price shocks to investigate healthcare expenditure in the United States. Their approach distinguishes an identified income response from the correlations typically available in international observational data. This distinction is consequential because GDP and expenditure expressed in current United States dollars can move together through exchange rate and price changes. An international panel can establish whether an income association persists after accounting for observed demographic conditions and national effects, but coefficient stability alone cannot identify the financing process responsible for that association. Population ageing introduces a different relationship between need and realised expenditure. A greater share of older residents may increase demand for treatment, but chronological age does not directly measure morbidity, disability, or treatment intensity. Reviewing the expenditure implications of ageing, de Meijer and colleagues, 2013, show that demographic effects depend on underlying health and their interaction with broader expenditure drivers. Consequently, a national age share can be informative about population composition without providing a complete measure of expenditure pressure. The relevant empirical question is whether its association with spending remains distinguishable after accounting for income and persistent differences between economies.

Urbanisation creates similarly competing expectations. Concentrated settlement may facilitate access to providers and increase recorded healthcare consumption, while shared infrastructure and service organisation may alter the expenditure required to deliver care. These are theoretical possibilities rather than mechanisms identified by an urban population percentage. Cyril, Oldroyd, and Renzaho, 2013, demonstrate that urban environments encompass characteristics that simple settlement classifications cannot capture. The urban population share therefore measures spatial composition rather than healthcare accessibility, infrastructure quality, or institutional performance. Its expenditure association requires examination rather than an

assumed positive direction. Measurement of the outcome further bounds interpretation. Current health expenditure per capita records annual spending on healthcare consumption rather than capital investment, service quality, or health improvement. OECD, Eurostat, and World Health Organization, 2017, establish the accounting boundaries underlying this distinction. Higher expenditure can consequently reflect different combinations of financing, prices, and service use. This analysis retains the provider's monetary measure and interprets it as nominal expenditure. It does not treat spending differences as evidence of differences in healthcare effectiveness or population welfare.

The reviewed evidence establishes the relevance of income, demographic composition, and measurement choices, but does not determine whether positive pooled associations for these three indicators remain informative under the same conditional specification and coverage checks. The contribution pursued here is therefore bounded: to distinguish pooled international rankings from conditional relationships within economies, and to assess whether their interpretation survives changes in observation coverage and uncertainty estimation. This comparison avoids treating a larger geographical sample as sufficient novelty. Its value lies in identifying which conclusions remain stable and which depend on the analytical comparison. This study aims to assess how income per capita, population ageing, and urbanisation relate to national health expenditure per capita. The central research question asks whether their pooled associations persist after accounting for economy and year effects, and whether the resulting conclusions withstand alternative sample definitions and uncertainty calculations. Three linked objectives guide the analysis: estimating the income association conditional on demographic composition, assessing the conditional ageing relationship, and examining the conditional urbanisation relationship.

The empirical analysis uses 2,672 complete annual observations across 192 economies between 2010 and 2024, drawn from a source grid covering 2010 to 2025. No expenditure observations support analysis for the final requested year. Pooled rank correlations describe unadjusted relationships, while a panel specification with economy and year effects distinguishes conditional associations from persistent national differences and common annual shifts. Sample restrictions address sparse final year coverage and unequal observation histories. Alternative covariance calculations assess how dependence assumptions affect uncertainty, a distinction developed by Millo, 2017. These procedures strengthen interpretation through transparent comparisons rather than establish causal identification. The findings identify a positive income association that remains less than proportional across the implemented sample checks. In contrast, the positive pooled demographic correlations do not translate into equally conclusive conditional estimates. The ageing relationship remains imprecise, while the statistical interpretation of urbanisation changes with the covariance calculation. This analysis contributes by showing that international expenditure rankings, conditional coefficient patterns, and inferential stability provide different information. For expenditure planning, that distinction supports using income responsiveness as a comparative benchmark while avoiding automatic spending adjustments based solely on national ageing or urbanisation shares.

2. Theory, Conceptual Framework and Research Question Development:

This analysis frames health expenditure as the interaction between economic resources, population needs, and the spatial organisation of service delivery. Income influences the resources available to households and health systems, while demographic composition and urbanisation shape demand and access. These relationships are interdependent because greater need produces expenditure only when financing and service capacity permit care. The outcome is current health expenditure per capita, measured in current United States dollars. It captures spending rather than service quality, financial protection, or population health. The predictors are income per capita, the population share aged 65 and above, and the urban population share. They enter the framework as separate observed measures rather than an aggregated index. Income per capita represents the economic resources potentially available to finance healthcare. Higher income can relax household budget constraints and expand the revenue available for collective financing. Providers may respond to stronger purchasing capacity by expanding services and adopting more expensive treatments. This resource constraint mechanism supports a positive association between income and expenditure, but does not establish that additional spending improves health.

The strength of this relationship depends on how economic resources translate into healthcare purchasing. Savings, competing public priorities, and restrictions on service supply can weaken expenditure responses. Baltagi and Moscone, 2010, identify healthcare as a necessity within their panel analysis of OECD economies, indicating that expenditure need not increase proportionately with income. That finding supports an income relationship without justifying a universal elasticity across economies. Global evidence also challenges a uniform response. Baltagi and colleagues, 2017, report variation in income elasticity across geographical and income groups. This analysis therefore examines the association between observed income and expenditure without assuming that every economy converts additional resources into spending at the same rate. Because both monetary measures use current dollars, their association can also reflect shared inflation and exchange rate movements.

RQ1: How is income per capita associated with health expenditure per capita after accounting for population ageing and urbanisation?

Population ageing represents a change in demographic composition, measured by the proportion of residents aged 65 and above. A larger older population can increase demand for continuing treatment and support. However, chronological age is an incomplete measure of healthcare need. The expenditure implications depend on whether additional years of life involve good health, disability, or intensive treatment. This distinction creates competing expectations. Greater survival may increase the number of people requiring care, while healthier ageing may postpone expensive treatment. Breyer, Costa Font, and Felder, 2010, show why population ageing alone provides an incomplete explanation of expenditure growth. Their analysis places demographic change within a wider relationship involving health status, medical progress, and healthcare delivery. The review by de Meijer and colleagues, 2013, further identifies health, disability, and medical technology as conditions shaping expenditure responses to ageing. Costa Font and Levaggi, 2020, similarly argue that costly innovation and chronic conditions matter alongside age composition. These mechanisms justify examining the observed demographic association without attributing it entirely to age. The available population share does not distinguish these underlying channels, so this analysis retains a research question rather than imposing an unconditional positive hypothesis.

RQ2: How is the population share aged 65 and above associated with health expenditure per capita after accounting for income and urbanisation?

Urbanisation represents the concentration of residents in settlements classified as urban. Spatial concentration can reduce travel barriers and support specialised services, increasing the opportunity to obtain treatment. Greater proximity between patients and providers can therefore translate previously unmet demand into expenditure. This mechanism concerns access to services rather than a direct effect of urban residence on spending. A competing mechanism operates through service organisation and prevention. Concentrated populations may allow infrastructure and facilities to serve more residents, while effective planning can reduce some environmental health risks. Conversely, unequal access and adverse living conditions can increase need without ensuring treatment. Rydin and colleagues, 2012, explain how urban health depends on interactions between infrastructure, planning, governance, and inequality rather than urban growth alone. These competing processes make the expected expenditure direction uncertain. Measurement also limits interpretation. Cyril, Oldroyd, and Renzaho, 2013, distinguish the complexity of urban environments from simple classifications of urban residence. The urban population share used here measures settlement composition, not provider density, infrastructure quality, or conditions within informal settlements. This analysis consequently examines its association with expenditure without treating it as a direct measure of healthcare access or institutional performance.

RQ3: How is the urban population share associated with health expenditure per capita after accounting for income and population ageing?

The conceptual framework links three observed predictors to one observed expenditure outcome through conditional associations. Income represents resource availability, population ageing represents demographic composition, and urbanisation represents settlement composition. The proposed mechanisms explain why these measures may relate to spending; they are not separately measured pathways. The workbook provides 2,672 complete economy and year observations across 192 economies, with usable expenditure observations spanning 2010 to 2024. The requested scope extends to 2025, but no expenditure observations support that final year. The research questions therefore concern the available observations and permit positive, negative, negligible, or inconclusive relationships without implying causal identification.

3. Data:

This analysis documents data provenance, reconstructs the analytical sample, and defines the observed measures supporting comparisons across economies. It reports verified coverage, missingness, consistency checks, and descriptive statistics without treating proposed estimation procedures as completed analyses.

3.1 Data Sources, Population, and Sample Construction:

The dataset combines four annual series from the World Bank World Development Indicators through API version 2. The World Bank provides the dissemination platform, while the underlying sources include national statistical agencies, the World Health Organization, and the United Nations Population Division. World Bank, 2015, documents the indicator system and its compilation framework. The supplied workbook preserves the extracted values, indicator identifiers, retrieval routes, extraction timestamp, and source update dates. Its live database extraction must be distinguished from the earlier published documentation.

Health expenditure originates from the World Health Organization Global Health Expenditure Database. Its interpretation follows the distinction between current healthcare consumption and capital expenditure established by OECD, Eurostat, and World Health Organization, 2017. World Health Organization, 2024, documents the reporting delays affecting international expenditure statistics. Population ageing and urbanisation originate from United Nations demographic series. United Nations, 2024, and United Nations, 2019, provide their demographic and settlement measurement context; these publications do not establish the exact upstream releases incorporated into the workbook. The unit of analysis is an economy observed annually. The empirical setting covers national healthcare expenditure alongside economic and demographic conditions across reporting economies. GDP and health expenditure represent annual monetary flows expressed per resident. Population ageing and urbanisation represent population composition, expressed as percentages rather than annual flows. Annual matching supports comparisons between expenditure and socioeconomic conditions recorded for the same reporting year. The target population comprises economies worldwide during 2010 to 2025. The accessible frame comprises the 217 economies represented in the workbook after excluding World Bank regional and income aggregates. Selection follows data availability rather than probability sampling. The source grid contains 3,472 possible observations, corresponding to 217 economies across 16 years. Retention requires observed values for all four indicators.

Table 1: Sample construction

Stage	Economies Retained	Observations Retained	Implemented Rule
Eligible source grid	217	3,472	Individual economies observed within 2010 to 2025
Observed health expenditure	193	2,697	Remove 775 records without expenditure
Complete values across all four indicators	192	2,672	Remove another 25 records without GDP per capita
Audited descriptive sample	192	2,672	No additional exclusions during verification

The final panel is unbalanced. Individual economies contribute between 2 and 15 observations. Of the retained economies, 161 contribute 14 observations and 22 contribute 15. The remaining nine contribute between 2 and 13. Twenty-five economies in the source frame contribute no complete observations. The workbook records the eligibility rules, but does not provide a dated preregistration establishing when they were adopted.

3.2 Data Integration, Cleaning, and Quality Assurance:

Integration uses the World Bank economy identifier and reporting year as the joint key. Each record contains one value per indicator for that economy and year. This arrangement preserves the distinction between observational units and measured

variables described by Wickham, 2014. The audit identified zero duplicate keys in both the source grid and analytical sheet. Reconstructing complete records reproduced all 2,672 analytical observations, with zero discrepancies in their identifiers, years, or indicator values. The integration retains the provider's annual reporting labels. No frequency conversion, fiscal calendar adjustment, interpolation, or additional currency conversion was applied. Both monetary indicators remain in current United States dollars. Their values therefore incorporate price and exchange rate movements alongside differences in economic activity and expenditure. The extract contains revised historical observations rather than a reconstruction of information available at each historical date. Missing values remain unavailable observations rather than zeros. Health expenditure is missing in 775 source records, representing 22.32 percent of the grid. GDP per capita is missing in 133 records, representing 3.83 percent. These losses overlap in 108 records. Population ageing and urbanisation have no missing values within the source grid. GDP missingness affects 31 economies; expenditure missingness affects every economy because the expenditure series contains no observations for 2025.

Table 2: Annual missingness and complete observation coverage

Year	Possible Observations	Missing GDP Per Capita	Missing Health Expenditure	Complete Observations
2010	217	4	29	188
2011	217	3	28	189
2012	217	5	28	188
2013	217	5	26	190
2014	217	4	26	190
2015	217	5	26	190
2016	217	6	26	190
2017	217	6	25	190
2018	217	6	24	191
2019	217	6	24	190
2020	217	7	24	190
2021	217	7	25	189
2022	217	8	26	188
2023	217	13	26	187
2024	217	17	195	22
2025	217	31	217	0

Complete observation selection preserves reported measurements but does not establish that the retained sample represents excluded observations. Hughes and colleagues, 2019, explain that the appropriateness of deletion depends on the missingness process. White and Carlin, 2010, likewise show that the relative performance of deletion and imputation depends on assumptions rather than a universal preference for either method. This analysis therefore reports the selection explicitly without claiming that missingness is random. No imputation model was constructed. Carpenter and Smuk, 2021, emphasise the assumptions required to justify missing data procedures, while Jakobsen and colleagues, 2017, distinguish assessment of missingness from the implementation of imputation. Here, the recorded information supports identification of unavailable values but does not establish their underlying causes. The retained monetary values are finite and strictly positive, and both population percentages lie between zero and 100. No observations were trimmed or winsorised. Extreme values remain as reported because range checks alone do not establish measurement error. The audit verified internal consistency with the source sheet; it did not independently validate national reporting systems or harmonise changes in national definitions.

3.3 Variable Measurement, Construction, and Validation:

This analysis uses four directly observed indicators without constructing latent variables or composite indices. GDP per capita measures economic output per resident rather than household disposable income. Baltagi and Moscone, 2010, and Baltagi and colleagues, 2017, provide evidence supporting its relevance to expenditure comparisons while showing that the income relationship need not be uniform across economies. The population share aged 65 and above measures demographic composition rather than morbidity or care dependency. Breyer, Costa Font, and Felder, 2010, and de Meijer and colleagues, 2013, explain why expenditure implications depend on health status and service requirements as well as chronological age. Urbanisation measures the urban population share rather than infrastructure quality or provider availability. Cyril, Oldroyd, and Renzaho, 2013, demonstrate the distinction between settlement classification and the wider characteristics of urban environments. These distinctions bound interpretation of the observed indicators.

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
Health expenditure per capita	Outcome	Annual current health expenditure divided by population; provider calculated	World Bank API version 2, WHO source	Current US dollars per resident, annual	Original level; higher values indicate greater nominal expenditure	Exclude incomplete records	2,697 source values; 2,672 retained; excludes capital expenditure
GDP per capita	Predictor	Annual GDP divided by population; provider calculated	World Bank API version 2	Current US dollars per resident, annual	Original level; higher values indicate greater nominal output per resident	Exclude incomplete records	3,339 source values; 2,672 retained; not household income
Population	Predictor	Residents aged 65 and	World Bank API	Percent, annual	Original percentage; higher	Exclude records	3,472 source values;

Variable	Analytical Role	Definition and Construction	Source and Identifier	Unit and Frequency	Transformation and Direction	Missing Value Rule	Coverage and Limitation
ageing		above as a percentage of total population	version 2, United Nations source		values indicate an older population composition	missing any study indicator	2,672 retained; does not measure health status
Urbanisation	Predictor	Urban residents as a percentage of total population, using national definitions	World Bank API version 2, United Nations source	Percent, annual	Original percentage; higher values indicate greater urban concentration	Exclude records missing any study indicator	3,472 source values; 2,672 retained; national definitions limit comparability

The four indicator pages identify Creative Commons Attribution 4.0 licensing. Indicator identifiers and source links permit verification against the provider, while the archived workbook preserves the values actually analysed. No logarithms, growth rates, interactions, population weights, or inflation adjustments were constructed. Differences between population percentages represent percentage point differences, not percentage changes.

Table 4: Descriptive statistics for the complete observation sample

Indicator	Valid Observations	Mean	Standard Deviation	Median	Minimum	Maximum
Health expenditure per capita, US dollars	2,672	1,225.01	2,025.11	366.97	11.77	13,473.19
GDP per capita, US dollars	2,672	16,390.35	26,425.52	5,980.99	216.73	256,799.91
Population aged 65 and above, percent	2,672	8.73	6.48	6.04	0.86	37.32
Urban population, percent	2,672	59.01	22.77	60.89	10.98	100.00

Statistics give equal weight to each retained observation. Standard deviations use the sample denominator. Monetary means exceed their medians, indicating concentration of higher values in the upper portion of the observed distributions. These summaries describe the available economy and year records rather than expenditure or income experienced by the average person worldwide.

3.4 Analytical Framework, Identification, and Reproducibility:

The implemented analysis is descriptive. It establishes coverage, distributions, missingness, and consistency of the four observed measures. No regression coefficients, conditional associations, or causal effects have been estimated. Consequently, no baseline equation, estimator, clustering procedure, or hypothesis decision is reported. Coverage differences constrain temporal interpretation. Annual sample averages can change because different economies report data, even when expenditure within individual economies does not change. This concern is strongest in 2024, when complete coverage falls to 22 economies. The absence of expenditure observations in 2025 prevents expenditure analysis for that year. The pooled summaries also combine persistent differences between economies with changes within economies and should not be interpreted as either component separately. Selection checks identify observable differences between retained and excluded records. Among the 667 excluded records with observed GDP per capita, mean GDP per capita is US dollars 29,327.97, compared with US dollars 16,390.35 in the retained sample. Mean population ageing and urbanisation are also higher among excluded records, at 10.68 percent and 68.05 percent respectively. These comparisons demonstrate compositional differences but do not identify the missingness mechanism or quantify selection bias.

Reproducibility rests on retaining source values separately from the analytical sample and making the selection rule executable. Peng, 2011, and Sandve and colleagues, 2013, emphasise the connection between computational results, input data, and documented processing. The accompanying audit script reconstructs complete observations, checks identifier uniqueness and measurement ranges, verifies agreement with the analytical sheet, and recalculates coverage and descriptive statistics. The audit reproduces calculations from the supplied extraction rather than independently reproducing the underlying national statistics. This distinction follows Goodman, Fanelli, and Ioannidis, 2016, and the National Academies of Sciences, Engineering, and Medicine, 2019. Providing executable checks alongside data also addresses the practical documentation requirements examined by Stodden, Seiler, and Ma, 2018. The verified alignment concerns identifiers, annual timing, original measurement units, and complete observation selection; it does not establish causal identification or eliminate differences in national statistical practices.

4. Methods:

4.1 Research Design and Analytical Sample:

This analysis uses an observational annual panel to distinguish pooled international expenditure associations from conditional relationships within economies. The estimands are the expenditure elasticity associated with income and the expenditure differences associated with population ageing and urbanisation, conditional on the other predictors, economy effects, and year effects. The unit of analysis is an economy observed in a reporting year. The baseline sample comprises 2,672 complete observations across 192 economies between 2010 and 2024. Table 1 documents sample construction, while Table 3 defines the indicators and their measurement limitations. The panel is unbalanced, with individual economies contributing between 2 and 15 observations. Complete observation selection supplies a consistent estimation sample across the three predictors but does not establish representativeness. As Hughes and colleagues, 2019, explain, the implications of excluding incomplete records depend on the missingness process. Useful estimation variation comes from changes within economies after accounting for common annual shifts. Economy effects absorb persistent national characteristics, while year effects absorb annual influences shared across economies. These adjustments do not remove unobserved influences that vary simultaneously across economies and time. Reverse causality, measurement error, reporting selection, and shared monetary movements remain possible explanations for estimated relationships. The design therefore supports conditional association rather than causal identification.

4.2 Model Specification and Measurement Alignment:

The implemented baseline specification is

$$\ln H_{it} = \alpha_i + \lambda_t + \beta_1 \ln Y_{it} + \beta_2 A_{it} + \beta_3 U_{it} + \varepsilon_{it}.$$

Here, H_{it} denotes current health expenditure per capita, Y_{it} denotes GDP per capita, A_{it} denotes the population percentage aged 65 and above, and U_{it} denotes the urban population percentage. The indices i and tidentify economies and reporting years.

The terms α_i and λ_t represent economy and year effects, respectively. The coefficients β_1, β_2 and β_3 describe conditional associations, and ε_{it} is the regression disturbance. Equation 1 includes all three observed predictors contemporaneously. Each predictor conditions the estimated relationship of the others, without being interpreted as a mediator or an independently assigned exposure. No coefficient sign restrictions are imposed. Natural logarithms of the monetary indicators express their relationship proportionally and reduce the influence of differences in nominal scale. All retained monetary observations are strictly positive, so logarithmic transformation causes no additional sample loss. Population percentages remain on their original scale. Accordingly, β_1 is an elasticity, whereas β_2 and β_3 are changes in logarithmic expenditure associated with one percentage point changes in their respective indicators.

For interpretation, a 10 percent income increase corresponds to an expenditure difference of $100\left[1.1^{\beta_1} - 1\right]$ percent. A one percentage point demographic change corresponds to $100\left[\exp\left(\beta_j\right) - 1\right]$ percent, where j identifies the relevant demographic coefficient. Confidence interval endpoints undergo the same monotonic transformations. Both monetary indicators retain their current United States dollar denomination. The analysis introduces no deflator or additional exchange rate conversion. Consequently, estimated relationships concern nominal expenditure and may incorporate shared currency and price movements.

4.3 Estimation and Statistical Inference:

Equation 1 is estimated by ordinary least squares with economy and year indicators. Computation first projects the outcome and predictors onto the fixed effect design and then estimates the relationship between their residuals. This projection approach accommodates the unbalanced panel without relying on a simple double demeaning formula. Every retained observation receives equal weight. Baseline uncertainty uses an economy clustered covariance estimator:

$$\widehat{V}_C = \frac{G}{G-1}\frac{N-1}{N-K} B\left[\sum_{i=1}^{G} s_i s_i^{'}\right] B, \qquad s_i = \sum_{t \in \mathcal{T}_i} \tilde{x}_{it}\, \hat{\varepsilon}_{it}, \qquad B = \left(\tilde{X}'\tilde{X}\right)^{-1}.$$

Here, G is the number of economies, N is the number of observations, and K is the rank of the complete regression design, including fixed effects and predictors. The set $\mathcal{T}_i$ contains the observed years for economy i. The vector $\tilde{x}_{it}$ contains the three predictors after projection on the economy and year indicators, and $\tilde{X}$ stacks these vectors. The term $\hat{\varepsilon}_{it}$ is the fitted residual, s_i is the economy level score sum, and B is the inverse predictor cross product matrix. The baseline calculation uses 192 clusters and a full design rank of 209. Two-sided tests and 95 percent confidence intervals use the student distribution with 191 degrees of freedom. Equation 2 permits heteroskedasticity and dependence within economies under the conditions supporting clustered inference. It does not accommodate every form of dependence between economies. MacKinnon, Nielsen, and Webb, 2023, provide the methodological basis for distinguishing these dependence assumptions. An alternative covariance calculation evaluates sensitivity to dependence across economies and over time:

$$\hat{V}_D = \frac{N}{N-K} B\left[\Gamma_0 + \sum_{\ell=1}^{2}\left(1 - \frac{\ell}{3}\right)\left(\Gamma_\ell + \Gamma_\ell^{'}\right)\right] B, \quad S_t = \sum_{i \in \mathcal{J}_t} \tilde{x}_{it}\, \hat{\varepsilon}_{it}, \quad \Gamma_\ell = \sum_{t=\ell+1}^{T} S_t\, S_{t-\ell}^{'}.$$

Here, $\hat{V}_D$ is the implemented Driscoll and Kraay covariance estimator, S_t is the score sum across economies observed in year t, and $\mathcal{J}_t$ identifies those economies. The matrix Γ_ℓ is the score cross product at annual lag ℓ, with $\Gamma_0 = \sum_{t=1}^{T} S_t\, S_t^{'}$. The number of observed years is T. Equation 3 uses a Bartlett kernel with two annual lags, and its confidence intervals use $T - 1$ degrees of freedom. This alternative changes uncertainty estimates while preserving the coefficients and observations. Following the distinction between panel covariance estimators discussed by Millo, 2017, it is treated as a sensitivity calculation rather than a universally preferable correction. Its interpretation remains constrained by the baseline panel's 15 observed years.

4.4 Diagnostics, Sensitivity Analysis, and Reproducibility:

Processing begins with verification of the source and analytical sheets, economy and year keys, numerical values, and measurement ranges. Complete records are reconstructed from the source sheet and matched against the analytical sheet. Monetary logarithms are then constructed, followed by descriptive statistics, pooled correlations, fixed effect estimation, and sensitivity analyses. No missing values are replaced by zero, imputed, or interpolated. No observations are trimmed or winsorised. Pooled Spearman correlations use average ranks for tied observations and describe monotonic associations without adjustment for national or annual effects. Their significance tests are not used because repeated observations within economies do not constitute independent draws. Identification of the three conditional coefficients is checked through the rank of the predictor matrix after removing fixed effects. Collinearity is assessed using variance inflation factors calculated from these residualised predictors. The reported fit measure is one minus the ratio of the fitted residual sum of squares to the outcome sum of squares remaining after projection on fixed effects. It measures the additional fit supplied by the three predictors, rather than their contribution to total expenditure variation. Numerical verification compares the projection-based coefficients and clustered standard errors with those obtained from the complete regression design containing explicit fixed effect indicators. This check evaluates implementation agreement, not the substantive validity of the model.

Sample sensitivity addresses two coverage concerns. First, excluding 2024 removes the sparsely observed final year and retains 2,650 observations across 192 economies. Second, restricting coverage to economies observed in every year from 2010 through 2023 produces a balanced sample of 2,562 observations across 183 economies. Equation 1 is reestimated unchanged in both samples, with covariance adjustments and degrees of freedom recalculated for each design. Influence is assessed by excluding each economy sequentially and reestimating Equation 1. The resulting 192 estimates identify whether coefficient direction or magnitude depends heavily on a single economy. These exclusions are diagnostic comparisons and do not alter the baseline sample. Robustness is evaluated through coefficient magnitude, direction, interval estimates, and sensitivity to covariance assumptions rather than repeated significance alone. The estimation and sensitivity choices are exploratory and were not preregistered. Computation uses Python 3.12.14, NumPy 2.3.5, pandas 2.2.3, and SciPy 1.17.0. Least squares calculations use NumPy linear algebra routines, while SciPy supplies distribution functions and correlation calculations. The procedures are

deterministic and require no random seed. The replication package contains the input workbook, audit code, estimation script, software requirements, and numerical outputs. Its independently runnable script reproduces the archived coefficients, clustered standard errors, and confidence intervals for all three analytical samples. Maintaining this connection between inputs, processing, and outputs follows the computational documentation principles described by Sandve and colleagues, 2013.

5. Findings:

This analysis examines how income, population ageing, and urbanisation relate to health expenditure per capita. The findings distinguish pooled associations from conditional estimates using economy and year effects. Sample restrictions and alternative uncertainty calculations assess the sensitivity of the conclusions. The analytical sample contains 2,672 annual observations across 192 economies between 2010 and 2024. Retention requires observed values for all four indicators. Of 3,472 possible observations, 775 lack health expenditure and another 25 lack income despite having expenditure data. Coverage falls to 22 economies in 2024, while no expenditure observations support analysis for 2025. Complete observation selection therefore determines the population represented by the estimates. As Hughes and colleagues, 2019, explain, this selection does not establish that missingness is random or that excluded observations resemble retained observations. Health expenditure is distributed unevenly across the observed economies and years. Mean expenditure is US dollars 1,225.01 per resident, compared with a median of US dollars 366.97. The middle half of observations lies between US dollars 91.03 and US dollars 1,184.08. Income shows a similar distributional imbalance, with mean GDP per capita of US dollars 16,390.35 and a median of US dollars 5,980.99. These differences motivate analysis of proportional monetary relationships rather than allowing the largest nominal observations to determine comparisons in levels. The conditional model regresses the natural logarithm of health expenditure per capita on the natural logarithm of GDP per capita; the population share aged 65 and above, and the urban population share. All predictors enter contemporaneously. Economy effects absorb persistent differences between economies, while year effects absorb common annual shifts. Ordinary least squares estimate use standard errors clustered by economy, with finite sample correction and confidence intervals based on 191 degrees of freedom. The specification and sensitivity analyses are exploratory rather than preregistered.

Table 5: Pooled associations and conditional expenditure estimates

Predictor	Pooled Spearman Correlation	Conditional Coefficient	Clustered Standard Error	95 Percent Confidence Interval	p Value
Natural logarithm of GDP per capita	0.965	0.68585	0.06526	0.55713 to 0.81457	< 0.001
Population aged 65 and above, percentage points	0.748	Negative 0.00183	0.01131	Negative 0.02414 to 0.02049	0.872
Urban population, percentage points	0.692	Negative 0.00395	0.00458	Negative 0.01299 to 0.00509	0.390

Income displays the clearest conditional association with expenditure. Its estimated elasticity is 0.686, with a confidence interval entirely above zero. A 10 percent increase in GDP per capita corresponds to approximately 6.76 percent higher health expenditure per capita, with a 95 percent confidence interval from 5.45 percent to 8.07 percent. This answers the income research question with a positive association that is less than proportional. The result is consistent with the aggregate necessity interpretation reported by Baltagi and colleagues, 2017, although differences in samples and specifications prevent treating the estimates as directly interchangeable. The income estimate represents an association within economies after accounting for the included predictors and common annual effects. It does not establish that income growth causes expenditure growth. Both monetary indicators are measured in current United States dollars, so shared exchange rate movements and domestic price changes may contribute to their relationship. The estimate consequently concerns nominal expenditure responsiveness rather than changes in healthcare quantities or purchasing power. Population ageing has a positive pooled rank correlation with expenditure but an imprecise conditional coefficient. A one percentage point increase in the older population share corresponds to an estimated expenditure difference of negative 0.18 percent. Its confidence interval extends from negative 2.39 percent to positive 2.07 percent. The evidence therefore does not establish a directional conditional relationship between this demographic share and expenditure. It also does not demonstrate that ageing is economically irrelevant. The population share does not measure disability, morbidity, or treatment intensity, distinctions emphasised by de Meijer and colleagues, 2013.

Urbanisation shows the same distinction between pooled and conditional evidence. Its pooled Spearman correlation with expenditure is 0.692, whereas the conditional coefficient is negative 0.00395. A one percentage point increase in the urban population share corresponds to approximately 0.39 percent lower expenditure, but the confidence interval ranges from negative 1.29 percent to positive 0.51 percent. Under economy clustered inference, the data do not establish either a positive or negative conditional association. This finding concerns settlement composition rather than healthcare accessibility or urban infrastructure, consistent with the measurement distinction identified by Cyril, Oldroyd, and Renzaho, 2013. The pooled and conditional results reveal why national expenditure comparisons require distinctions between analytical scales. Economies and years with higher older population shares or urban population shares tend to rank higher in expenditure. However, these pooled patterns do not translate into clearly estimated conditional relationships after accounting for income, persistent economy differences, and common annual variation. The comparison does not identify which adjustment accounts for the difference. The three predictors jointly account for 37.60 percent of the variation in logarithmic expenditure remaining after removing economy and year effects. Variance inflation factors calculated from the predictors after removing those effects range from 1.014 to 1.064. Predictor overlap is therefore limited in this specification and does not explain the imprecision of the demographic coefficients.

Table 6: Sensitivity to observation coverage

Analytical Sample	Observations	Economies	Income Elasticity	Ageing Coefficient	Urbanisation Coefficient
All complete observations, 2010 to	2,672	192	0.68585	Negative 0.00183	Negative 0.00395

Analytical Sample	Observations	Economies	Income Elasticity	Ageing Coefficient	Urbanisation Coefficient
2024					
Excluding 2024	2,650	192	0.68404	Negative 0.00234	Negative 0.00394
Balanced coverage, 2010 to 2023	2,562	183	0.70251	Negative 0.00190	Negative 0.00388

Removing the sparsely observed final year changes the income elasticity from 0.68585 to 0.68404. Restricting the sample to 183 economies with complete coverage throughout 2010 to 2023 produces an elasticity of 0.70251, with a 95 percent confidence interval from 0.56586 to 0.83917. Ageing and urbanisation remain imprecisely estimated under economy clustered inference in both restricted samples. These comparisons indicate that the principal coefficient pattern is not driven by the 22 observations from 2024. The balanced comparison nevertheless changes the represented economies and cannot establish the absence of selection bias. Sequentially excluding each economy produces income elasticities between 0.65718 and 0.71637. The positive income association therefore persists across all 192 individual economy exclusions. The ageing coefficient ranges from negative 0.00496 to positive 0.00273, indicating that its estimated direction is not stable across these exclusions. Urbanisation coefficients remain negative, ranging from negative 0.00574 to negative 0.00254. These ranges describe coefficient sensitivity and do not establish statistical precision.

Inference for urbanisation changes under an alternative covariance calculation. Driscoll and Kraay standard errors, using a Bartlett kernel with two annual lags, yield a standard error of 0.00175 and a p value of 0.041. The corresponding coefficient interval extends from negative 0.00771 to negative 0.00019. Income remains positively associated with expenditure, while ageing remains imprecise. The urbanisation conclusion is therefore sensitive to the treatment of dependence. Millo, 2017, explains the distinct dependence structures addressed by panel covariance estimators. With only 15 observed years, the alternative calculation provides a sensitivity assessment rather than decisive evidence of a negative urbanisation relationship. The findings establish a positive, less than proportional income association that persists across the implemented sample restrictions and individual economy exclusions. They do not establish a directional conditional ageing relationship. Urbanisation has a negative conditional estimate, but its statistical interpretation depends on the uncertainty calculation. The central empirical distinction is between strong positive pooled demographic rankings and substantially less conclusive conditional evidence.

6. Discussion:

National spending rankings can conceal relationships that do not persist within economies. Table 5 shows this distinction: income retains a positive conditional association with health expenditure, whereas positive pooled demographic correlations do not translate into comparably precise conditional estimates. The contribution lies in distinguishing the information contained in international expenditure rankings from the information contained in changes within economies. Vargas Bustamante and Shimoga, 2018, demonstrate that income elasticity estimates depend on sample composition and specification. This analysis extends that concern by showing that income, ageing, and urbanisation differ in their stability across analytical comparisons. Table 6 strengthens this interpretation because restricting temporal coverage leaves the principal coefficient pattern largely unchanged. The evidence therefore qualifies frameworks that treat positive international demographic correlations as sufficient evidence of expenditure responsiveness. The income relationship is consistent with a resource constraint interpretation, but its meaning is narrower than a demonstrated financing mechanism. The elasticity in Table 5 indicates that expenditure changes less than proportionately with income, suggesting that economic expansion does not translate mechanically into equivalent expenditure growth. Reeves and colleagues, 2014, identify fiscal and political influences on healthcare expenditure across European economies, illustrating why economic resources and spending decisions must remain conceptually distinct. Here, the persistence of the income association across Table 6 supports its empirical relevance without identifying the institutional process producing it. Because both monetary measures use current dollars, the relationship may also incorporate shared price and exchange rate movements. This changes the interpretation of income from a sufficient explanation of healthcare expansion to a stable nominal correlate whose institutional transmission remains outside the estimated relationship.

The demographic findings challenge deterministic interpretations of expenditure pressure without establishing that demographic needs are unimportant. Income is the most consistently estimated predictor, but this does not establish that it accounts for the largest share of expenditure growth. Dieleman and colleagues, 2017, distinguish demographic contributions from service price and intensity contributions in United States expenditure growth; the conditional associations in Table 5 answer a different question. Similarly, Breyer, Lorenz, and Niebel, 2015, distinguish age composition from longevity related expenditure processes. These comparisons explain why the imprecise ageing coefficient should qualify the use of a demographic proxy rather than overturn evidence about healthcare needs. The theoretical refinement is that population composition and realised expenditure occupy different positions in the analytical framework: an aggregate demographic share cannot substitute for the processes connecting need to financed treatment. Urbanisation exposes a distinction between coefficient stability and inferential stability. Its negative conditional estimate changes little across the samples in Table 6, yet its statistical interpretation changes under the alternative covariance calculation. A stable coefficient direction therefore provides insufficient grounds for concluding that urbanisation reduces expenditure. MacKinnon, Nielsen, and Webb, 2023, emphasise that reliable inference depends on the dependence structure and characteristics of the available clusters. The short temporal dimension makes this distinction consequential here. Coverage also affects interpretation: sparse final year reporting means that changes in observed international averages can reflect changes in represented economies. These findings add a methodological boundary to substantive interpretation: settlement composition should not become an expenditure policy lever merely because one uncertainty calculation produces a conventional significance result.

The international relevance lies in identifying which conclusions travel across sample definitions and which remain conditional on analytical choices. The income elasticity is close to the estimate reported by Acemoglu, Finkelstein, and Notowidigdo, 2013, using income variation generated by oil price shocks in the United States. Numerical proximity does not make the designs equivalent: their identification strategy and this international observational panel support different claims. Tables

5 and 6 instead provide a comparative benchmark for assessing nominal expenditure responsiveness across reporting economies. Decision makers can use the stable income association as a reference for expenditure monitoring, while avoiding automatic budget adjustments based solely on national ageing or urbanisation shares. The broader contribution is a separation of resource responsiveness, demographic composition, and inferential uncertainty, allowing international expenditure comparisons to inform planning without converting aggregate associations into unsupported causal prescriptions.

7. Conclusion and Implications:

Global expenditure planning becomes unreliable when national spending rankings are mistaken for relationships governing change within economies. This analysis shows that financial capacity retains a stable association with spending, whereas demographic and settlement composition provide less conclusive conditional evidence. Their joint consideration reveals an asymmetry between strong pooled rankings and uneven explanatory precision. The contribution is an empirical distinction between international spending patterns, conditional relationships, and the stability of statistical conclusions. This distinction refines resource constraint explanations by showing that population composition cannot automatically substitute for the processes translating needs into financed care. The evidence establishes associations rather than causal pathways. For decision makers, the findings support benchmarking expenditure responsiveness against available resources while testing whether demographic assumptions remain informative after accounting for persistent national differences. Budget teams should separate nominal financial changes from assumptions about service requirements and evaluate conclusions under alternative coverage and uncertainty calculations. Policymakers should strengthen reporting continuity and avoid automatic allocation adjustments derived solely from aggregate population profiles. Operationally, documenting exclusions, maintaining consistent measurement definitions, and distinguishing stable estimates from sensitive conclusions can improve planning transparency. These practices offer internationally relevant safeguards against overstated evidence and support more accountable decisions about the resources available for healthcare.

The available panel creates opportunities to strengthen measurement and identification. Unequal reporting histories and limited final year coverage motivate comparisons using harmonised reporting windows and alternative missing data assumptions. Current dollar measures invite replication using purchasing power adjustments and healthcare price information to distinguish financial movements from service expansion. Aggregate population indicators can be complemented by morbidity, disability, provider availability, and financing composition. Longer observation histories would strengthen assessments of dependence and structural change. Designs exploiting plausibly external financing changes could investigate causal responses, while institutional comparisons could establish where the observed relationships transfer and which financing arrangements condition them.

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