*International Journal of Scientific Research and Modern Education (IJSRME)*
*International Peer Reviewed - Refereed Research Journal, Website: www.crystalpen.in*
*Impact Factor: 7.137, ISSN (Online): 2455 - 5630, Volume 11, Issue 2, July - December, 2026*

# EXCHANGE RATE DYNAMICS AND HEALTH EXPENDITURE PER CAPITA ACROSS ECONOMIES ENGAGED IN INTERNATIONAL IMPORT TRADE

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

**Cite This Article:** Kannan Vishwanath & Lloyd Zulu, "Exchange Rate Dynamics and Health Expenditure Per Capita Across Economies Engaged in International Import Trade", International Journal of Scientific Research and Modern Education, Volume 11, Issue 2, July - December, Page Number 23-32, 2026.

**Copy Right:** © Crystal Pen Publication, 2026 (All Rights Reserved). This is an Open Access Article distributed under the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

**Type of Review:** Peer Reviewed as per |C|O|P|E| Guidance.

**Disclaimer:** The scholarly papers reviewed and published by Crystal Pen Publication, India, reflect the views and opinions of their respective authors and do not necessarily represent the views or opinions of Crystal Pen Publication. The publisher disclaims any responsibility for any harm, loss, or damage resulting from the use of the published content by any party.

**DOI:** https://doi.org/10.5281/zenodo.24050672

**Abstract:**

This analysis examines whether exchange rate dynamics exhibit distinct associations with health expenditure across importing economies, informing international debates on financing pressures. World Development Indicators provide 1,995 annual observations across 185 economies during 2013 to 2023. An exploratory panel model jointly estimates contemporaneous depreciation, preceding depreciation and rolling volatility, incorporating economy and year fixed effects with standard errors clustered by economy. A ten-percentage log point increase in contemporaneous depreciation is associated with 1.39% lower expenditure, with a 95% confidence interval indicating reductions between 0.44% and 2.32%. Preceding depreciation is imprecisely estimated, while the negative volatility association weakens after adjustment for multiple comparisons. Adding observations from 2024 changes estimates little, and excluding individual economies preserves coefficient directions. However, expenditure level specifications provide weaker evidence. These findings refine uniform transmission accounts by distinguishing timing, variability and measurement scale without identifying causal mechanisms. International expenditure surveillance should therefore assess proportional and absolute spending together and avoid interpreting currency associations as direct evidence of changes in service availability.

**Key Words:** Exchange Rate Dynamics; Health Expenditure; Health Financing; Importing Economies; Panel Data Analysis.

## 1. Introduction:

Currency depreciation can increase the domestic cost of international purchases while health financing systems face competing demands on limited resources. The relevant financing question extends beyond whether exchange rates change: it concerns whether those movements accompany changes in expenditure per person, whether the relationship persists into the following year, and whether currency variability carries additional information. These distinctions matter for interpreting expenditure pressures across importing economies. Higher financial expenditure can reflect higher purchasing costs rather than expanded provision, while lower expenditure does not independently establish reduced access. Kutzin, 2013, distinguishes health financing arrangements from health system performance, providing a basis for examining expenditure without treating it as a direct measure of coverage or service availability. International price transmission provides the conceptual link between currency movements and purchasing conditions. Gopinath and colleagues, 2020, demonstrate that dominant currency invoicing helps explain how exchange rates influence international prices and trade. Boz and colleagues, 2022, document variation in invoicing currencies across trading economies, indicating that participation in international trade does not imply uniform currency exposure. These findings motivate examining exchange rate dynamics across importing economies, but they do not establish a predetermined relationship with aggregate health expenditure. Purchasers may absorb higher costs through additional expenditure, maintain spending within existing allocations or reduce purchases. The resulting expenditure association therefore depends on responses that cannot be inferred from exchange rate movements alone.

Health financing research identifies a complementary set of domestic influences. Fan and Savedoff, 2014, associate expenditure patterns with income, technological change, cost pressures and financing institutions. Reeves and colleagues, 2014, show that healthcare expenditure responses during economic contraction also reflect revenue conditions and political decisions. Together, these contributions imply that external purchasing pressures interact with domestic financing arrangements rather than determine expenditure independently. They also distinguish the timing of currency movements from the timing of expenditure adjustment. Current depreciation may accompany contemporaneous spending differences, whereas earlier depreciation may remain relevant through subsequent adjustment. Neither relationship can be assumed to have the same direction or magnitude across economies. The closest reviewed evidence establishes international price transmission and domestic financing responses, but does not establish whether contemporaneous depreciation, preceding depreciation and recent currency variability exhibit distinct associations with health expenditure within a common international panel. Forbes, Hjortsoe and Nenova, 2018, further demonstrate that exchange rate transmission depends on the shocks generating currency movements. This makes a uniform interpretation of depreciation particularly restrictive. The empirical question requires separating currency direction, timing and variability while distinguishing persistent differences across economies from changes within them. It also requires examining whether conclusions depend on measuring expenditure proportionally or in absolute monetary units. These are the bounded analytical contributions pursued here, rather than claims to identify a new causal mechanism.

This study aims to examine the associations between exchange rate dynamics and health expenditure per capita across economies engaged in international import trade. The central research question asks how annual depreciation, depreciation in the

preceding year and rolling exchange rate volatility relate to expenditure after accounting for persistent economy differences and common annual shifts. The analysis combines World Development Indicators series on official exchange rates, current health expenditure per capita at purchasing power parity and merchandise imports. The principal sample contains 1,995 annual observations across 185 economies from 2013 to 2023. Merchandise imports establish eligibility, while the three currency indicators represent observed dimensions of exchange rate dynamics. A joint panel specification includes economy and year fixed effects, with standard errors clustered by economy. Additional analyses examine pooled rank correlations, expenditure levels, extended coverage through 2024 and the exclusion of individual economies. The findings distinguish contemporaneous association from persistence and variability. Greater current depreciation is associated with lower proportional health expenditure, while preceding depreciation does not exhibit a precisely estimated additional relationship. The negative volatility association is more sensitive to adjustment for multiple comparisons and outcome scaling. Adding the sparsely represented final year changes the logarithmic estimates little, but expenditure level specifications provide weaker evidence. These results contribute a differentiated account of currency conditions and health financing: directional stability across sample checks does not imply equal precision across measures or establish causal transmission. For international expenditure monitoring, the analysis supports examining proportional and absolute spending together and interpreting currency indicators as contextual evidence rather than direct measures of health service outcomes.

**2. Theory, Conceptual Framework and Research Questions Development:**

This analysis connects exchange rate transmission theory with the health financing transition to examine how currency movements relate to health expenditure per capita across importing economies. International transactions expose purchasers to changes in the domestic currency cost of foreign goods, while financing arrangements shape their capacity to absorb those changes. In their 2014 analysis, Fan and Savedoff associate health spending patterns with income, technological change, cost pressures and financing institutions. Their framework implies that external price pressures interact with domestic financing decisions rather than determine expenditure independently. The relevant outcome is therefore expenditure per person, measured at purchasing power parity, rather than the quantity or availability of health services. The conceptual framework distinguishes three observed dimensions of exchange rate dynamics: annual currency depreciation, depreciation in the preceding year and rolling exchange rate volatility. These measures capture the direction, timing and variability of currency movements. They are calculated indicators rather than components of an estimated latent construct. The outcome is current health expenditure per capita in current international dollars at purchasing power parity. Merchandise imports establish participation in import trade without measuring the imported share of health expenditure. The framework examines associations between these observed measures and does not identify currency movements as exogenous shocks.

Annual currency depreciation measures the percentage logarithmic change in the official annual average exchange rate, expressed as domestic currency units per United States dollar. Positive values indicate depreciation. When purchases are invoiced in dollars, depreciation can increase their domestic currency cost even when foreign suppliers leave invoice prices unchanged. Gopinath and colleagues, 2020, demonstrate that dominant currency invoicing helps explain international price transmission and trade responses. Applying this mechanism to health expenditure provides a theoretical expectation about purchasing pressure, rather than an established finding about aggregate health spending. The expected expenditure response is ambiguous because expenditure combines prices and quantities. Purchasers facing higher costs may reduce purchases, maintain spending within existing budgets or increase expenditure to preserve provision. Purchasing power parity improves international comparability but does not transform current expenditure into a direct measure of health service volumes. Consequently, depreciation could accompany higher measured expenditure even when purchasing conditions deteriorate. Price transmission also depends on supplier responses. Amiti, Itskhoki and Konings, 2014, show that imported inputs and variable markups contribute to differences in exchange rate transmission across firms. Their evidence establishes that currency changes need not translate proportionately into purchaser prices. Together, these competing responses justify examining the direction and magnitude of the observed relationship without imposing a universal negative hypothesis.

RQ1: What association exists between annual currency depreciation and health expenditure per capita at purchasing power parity across importing economies?

Depreciation in the preceding year introduces the timing of expenditure adjustment. Current spending commitments may reflect prices, purchasing decisions and budget allocations established before the observation year. Earlier depreciation could therefore remain associated with current expenditure after its initial occurrence. This temporal argument differs from the contemporaneous relationship because it concerns the persistence of adjustment rather than the immediate purchasing pressure.

The direction remains uncertain. Delayed budget expansion could raise expenditure following depreciation, while postponed purchases or expenditure restraint could lower it. Reeves and colleagues, 2014, document associations between revenue losses, political decisions and healthcare expenditure changes across European economies. Their findings support the importance of financing responses but do not establish that earlier depreciation produces a particular subsequent expenditure response. This analysis represents the temporal dimension using the preceding annual depreciation measure. The indicator allows a comparison between earlier currency movements and current expenditure without treating their chronological ordering as evidence of causation. A weak association would remain compatible with rapid adjustment, offsetting responses or differences across economies.

RQ2: What association exists between currency depreciation in the preceding year and current health expenditure per capita at purchasing power parity across importing economies?

Rolling exchange rate volatility captures variability rather than depreciation alone. It is measured as the sample standard deviation of three annual logarithmic exchange rate changes, ending in the observation year. Economies can experience similar current depreciation while displaying different recent patterns of currency variation. The volatility measure therefore distinguishes the stability of the recent exchange rate path from its current direction. Variation in purchasing costs can complicate expenditure planning. Purchasers may defer commitments when future costs become difficult to anticipate, while other purchasers may accelerate purchases or allocate additional resources to preserve continuity. Bloom, 2014, explains how uncertainty can influence

expenditure decisions through postponement and adjustment behaviour. This provides a theoretical rationale for examining currency variability, although realised exchange rate volatility does not directly measure expectations or perceived uncertainty.
The distinction prevents an interpretation of higher volatility as direct evidence of institutional weakness or procurement disruption. Neither mechanism is measured by the available indicators. The analysis instead examines whether greater variation in recent annual currency changes accompanies different expenditure levels. Because the volatility calculation incorporates the current and preceding depreciation observations, it represents a related dimension of exchange rate dynamics rather than an independent external exposure.
RQ3: What association exists between rolling exchange rate volatility and health expenditure per capita at purchasing power parity across importing economies?

These research questions preserve the distinction between theoretical mechanisms and relationships observable in the data. They permit positive, negative, weak or inconclusive associations without making statistical significance a condition for reporting results. The framework supports an assessment of expenditure patterns while maintaining the boundary between aggregate financial expenditure and the health resources or services that expenditure purchases.

**3. Data:**

This analysis documents source provenance, constructs the analytical sample and translates exchange rate dynamics into reproducible measures. Verified coverage, missingness and descriptive statistics establish the empirical basis for examining health expenditure across importing economies.

**3.1 Data Sources, Population, and Sample Construction:**

The dataset combines three annual series from World Development Indicators, source identifier 2, accessed through the World Bank Indicators API, version 2. Official exchange rates originate from the International Monetary Fund and use series PA.NUS.FCRF. Health expenditure originates from the World Health Organization Global Health Expenditure Database and uses series SH.XPD.CHEX.PP.CD. Merchandise imports originate from the World Trade Organization and use series TM.VAL.MRCH.CD.WT. The World Bank indicator pages provide stable access links and identify the data licence as Creative Commons Attribution 4.0. The source grid covers 2010 to 2025. Its extraction date and database update stamp are recorded in the workbook and both postdate 2025. Consequently, the observations represent retrospectively available historical data rather than a database vintage frozen at the end of the observation window. Publication dates are not assigned to the undated World Bank indicator pages.

The unit of analysis is the economy within an observation year. The target population comprises economies participating in international merchandise import trade during the specified period. The accessible frame contains 207 economies with positive reported merchandise imports in at least one year. Regional aggregates are excluded. This is an availability based enumeration of eligible reporting economies rather than a probability sample. The source grid contains 3,312 observations, representing 207 economies across 16 years. Exchange rates are annual period averages. Merchandise imports are annual monetary flows, while health expenditure measures annual current spending per person at purchasing power parity. These measures are neither stocks nor values observed only at year end. Analytical eligibility requires positive health expenditure, positive current merchandise imports and positive exchange rates in the current year and preceding three years. The exchange rate requirement permits construction of three consecutive annual currency changes. The workbook records these rules, but does not provide a dated preregistration or decision history establishing when they were adopted.

Table 1: Sequential sample construction

| Stage | Economies Retained | Observations Retained | Documented Exclusion or Rule |
|---|---|---|---|
| Initial eligible frame | 207 | 3,312 | Positive merchandise imports in at least one year within 2010 to 2025 |
| Sufficient observation history | 207 | 2,691 | Exclude 621 observations from 2010 to 2012 because the required currency history cannot be constructed entirely within scope |
| Available positive health expenditure | 189 | 2,089 | Exclude 602 observations with unavailable health expenditure |
| Complete positive exchange rate history | 185 | 2,021 | Exclude 68 observations lacking at least one required exchange rate |
| Available positive current merchandise imports | 185 | 2,017 | Exclude four observations with unavailable current imports |
| Verified analytical dataset | 185 | 2,017 | Unique economy and year combinations with all required measures |

Exclusions in Table 1 are sequential and mutually exclusive. The retained dataset is an unbalanced panel covering 2013 to 2024. Economies contribute between one and 12 observations, with a median of 11. Annual coverage ranges from 178 to 183 economies during 2013 to 2023, followed by 22 economies in 2024. No complete observations remain for 2025 because health expenditure is unavailable. These counts describe the constructed dataset rather than an estimator specific sample.

**3.2 Data Integration, Cleaning, and Quality Assurance:**

The series are aligned using World Bank economy identifiers and observation years. This creates one intended record for each economy and year. The audit identified no duplicate keys in either the source grid or analytical dataset. All 2,017 analytical records match eligible source records, and their linked exchange rates, import values and health expenditure values reproduce the corresponding source cells exactly. Annual observations retain their provider assigned years. No additional frequency conversion, currency conversion, inflation adjustment or temporal interpolation is applied. Health expenditure retains the provider's

purchasing power parity conversion and current international dollar basis. Exchange rates remain in domestic currency units per United States dollar, while imports remain in current United States dollars. Purchasing power parity comparability does not make the expenditure series a constant price measure. Across the source grid, exchange rates contain 129 unavailable observations affecting 27 economies, health expenditure contains 666 affecting all 207 economies, and imports contain 45 affecting nine economies. All economies have at least one unavailable health expenditure observation because the source grid includes 2025. Health expenditure availability falls from 188 economies in 2023 to 22 in 2024 and zero in 2025.

Unavailable source values remain explicitly marked as NA. The workbook does not distinguish every missing observation as unreported, structurally inapplicable or delayed. No missing values are replaced with zero, imputed or interpolated. Complete observation selection preserves the distinction between absent information and observed values, but does not establish that exclusion is unrelated to expenditure or currency conditions. Hughes and colleagues, 2019, explain why the validity of a missing data strategy depends on the missingness process rather than completeness alone. All available source exchange rates, expenditure values and import values are positive. The analytical audit also checks the positivity of logarithm inputs and reproduces the rolling calculations. Extreme currency changes remain unchanged because the workbook specifies no outlier threshold or verified correction for currency redenominations. Retaining these observations preserves source fidelity, while leaving their economic interpretation dependent on the underlying currency history.

**3.3 Variable Measurement, Construction, and Validation:**

The framework uses three calculated exchange rate indicators and one observed expenditure outcome. Merchandise imports determine eligibility rather than serve as an additional explanatory variable. No composite index, moderator, interaction or control variable is constructed. Equation 1 defines annual currency depreciation:

$$d_{it} = 100 \ln \frac{E_{it}}{E_{i,t-1}}$$

Here, $d_{it}$ is annual depreciation in percentage log points, $E_{it}$ is the official annual average exchange rate, iidentifies the economy and tidentifies the observation year. Positive values indicate depreciation against the United States dollar. Equation 2 defines depreciation in the preceding year:

$$\ell_{it} = d_{i,t-1}$$

Here, $\ell_{it}$ is lagged depreciation and $d_{i,t-1}$ is the annual currency change immediately preceding the expenditure observation. Equation 3 defines rolling exchange rate volatility:

$$v_{it} = \sqrt{\frac{\sum_{j=0}^{2}\left[d_{i,t-j} - \bar{d}_{it}\right]^2}{2}}, \qquad \bar{d}_{it} = \frac{\sum_{j=0}^{2} d_{i,t-j}}{3}$$

Here, $v_{it}$ is the sample standard deviation of three annual depreciation observations, j indexes the current and preceding two currency changes, and $\bar{d}_{it}$ is their arithmetic mean. The denominator is two because the implemented calculation uses the sample standard deviation of three observations.

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 |
|---|---|---|---|---|---|---|---|
| Health expenditure per capita | Outcome | Current health expenditure divided by population and expressed at purchasing power parity | World Bank, WHO; SH.XPD.CHEX.PP.CD | Current international dollars per person; annual | Level; higher values indicate greater expenditure per person | Exclude unavailable or nonpositive values | 2,646 available source observations; measures expenditure rather than service volume |
| Official exchange rate | Construction input | Official annual average domestic currency units per United States dollar | World Bank, IMF; PA.NUS.FCRF | Currency units per dollar; annual average | Level used in logarithmic ratios | Require positive current and preceding three rates | 3,183 available source observations; official rates may differ from transaction rates |
| Annual currency depreciation | Explanatory indicator | Equation 1 | Calculated from PA.NUS.FCRF | Percentage log points; annual | Positive values indicate depreciation | Exclude incomplete or invalid rate pairs | 2,017 analytical observations; logarithmic change rather than conventional percentage change |
| Lagged currency depreciation | Explanatory indicator | Equation 2 | Calculated from PA.NUS.FCRF | Percentage log points; annual | Positive values indicate depreciation in the preceding year | Require the preceding currency change | 2,017 analytical observations; timing alone does not establish causation |
| Rolling exchange rate volatility | Explanatory indicator | Equation 3 | Calculated from PA.NUS.FCRF | Percentage points on the logarithmic change scale; annual rolling measure | Higher values indicate greater recent currency variability | Require all three currency changes | 2,017 analytical observations; measures annual variability rather than variation within a year |
| Merchandise imports | Eligibility indicator | Annual merchandise import value | World Bank, WTO; TM.VAL.MRCH.CD.WT | Current United States dollars; annual flow | Positive values establish importing participation | Require positive current imports for analytical inclusion | 3,267 available source observations; does not measure health sector import dependence |

The audit recalculates Equations 1 to 3 independently from the source exchange rates. The largest absolute difference from the workbook calculations is below 0.000000000001. This verifies computational consistency without establishing that official exchange rates capture every relevant purchasing transaction.

Table 3: Descriptive statistics for the complete analytical dataset

| Indicator | Valid Observations | Mean | Standard Deviation | Median | Minimum | Maximum |
|---|---|---|---|---|---|---|
| Health expenditure per capita | 2,017 | 1,614.44 | 2,010.71 | 821.24 | 25.41 | 13,473.19 |
| Annual currency depreciation | 2,017 | 4.46 | 14.53 | 0.38 | −204.66 | 223.63 |
| Lagged currency depreciation | 2,017 | 4.72 | 15.87 | 0.82 | −105.95 | 476.80 |
| Rolling exchange rate volatility | 2,017 | 6.66 | 12.35 | 4.88 | 0.00 | 266.20 |

Table 3 pools the available economy and year observations without population weights. Economies with longer coverage therefore contribute more observations. The expenditure mean exceeds its median, indicating an asymmetric distribution. Currency measures also contain extreme observations. Volatility equals zero in 296 records, reflecting identical annual currency changes within the corresponding calculation windows.

**3.4 Analytical Framework, Identification, and Reproducibility:**

The implemented analysis is descriptive. It establishes coverage, sample composition, distributions and computational consistency for measures that support subsequent association testing. The analytical relationships of interest connect current health expenditure with contemporaneous depreciation, preceding depreciation and recent currency variability. These relationships do not identify causal effects. The data structure separates explanatory timing from information vintage. Lagged depreciation uses earlier observation years, and rolling volatility uses only the current and preceding currency changes. However, the underlying series are retrospectively available historical observations rather than archived real time releases. The construction therefore prevents later observation years from entering earlier rolling windows without claiming to reproduce information available to decision makers at each historical date.

The three currency indicators are mathematically related. Rolling volatility incorporates the contemporaneous and preceding depreciation observations, so separate substantive interpretations do not establish statistical independence. Current purchasing power parity expenditure also combines spending patterns with a current price measurement basis. These features constrain interpretation even when an observed association is precisely estimated. Coverage provides an additional boundary. The dataset contains 1,995 observations through 2023 and 22 in 2024. The limited final year changes geographical representation, while complete observation selection removes 22 economies entirely from the eligible frame. The verified sample construction documents these differences without treating the retained economies as representative of every importing economy. The workbook preserves source observations, availability flags, coverage counts, variable definitions and executable spreadsheet formulas. These materials allow the analytical records and calculated indicators to be traced to their inputs. This traceability follows the reproducibility emphasis articulated by Sandve and colleagues, 2013, while the independent recalculation verifies that definitions, temporal alignment and implemented transformations agree.

**4. Methods:**

**4.1 Research Design and Analytical Sample:**

This analysis uses an exploratory observational panel design to estimate conditional associations between exchange rate dynamics and health expenditure per capita. The unit of analysis is the economy within an observation year. The estimands are the partial linear associations of contemporaneous depreciation, preceding depreciation and rolling exchange rate volatility with logarithmic expenditure, conditional on economy and year fixed effects. The principal sample contains 1,995 observations across 185 economies during 2013 to 2023. The extended specification includes 22 additional observations from 2024. Both panels are unbalanced. Table 1 documents sample construction, while Table 2 provides variable definitions and measurement restrictions. The principal window follows the workbook's documented recommendation to assess the sparsely represented final year separately. No additional observations are lost when applying the logarithmic transformation because retained expenditure values are positive. Useful variation comes from changes within economies after removing differences common to each year. Economy fixed effects absorb persistent characteristics, while year fixed effects absorb common annual shifts. The design does not identify external currency shocks or separate exchange rate movements from concurrent domestic changes. Accordingly, coefficients represent conditional associations rather than causal effects. Earlier explanatory timing does not independently resolve confounding or reverse causality.

**4.2 Model Specification and Measurement Alignment:**

The baseline specification is presented in Equation 4:

$$\ln H_{it} = \alpha_i + \lambda_t + \beta_1 d_{it} + \beta_2 \ell_{it} + \beta_3 v_{it} + u_{it}$$

Here, $H_{it}$ denotes current health expenditure per capita at purchasing power parity, iidentifies the economy and tidentifies the observation year. The terms $\alpha_i$and $\lambda_t$ denote economy and year fixed effects. The indicators $d_{it}$, $\ell_{it}$ and $v_{it}$ represent contemporaneous depreciation, preceding depreciation and rolling volatility, respectively. Their coefficients are $\beta_1, \beta_2$ and $\beta_3$ while $u_{it}$ is the residual. Equations 1 to 3 define the explanatory indicators. Current depreciation compares consecutive annual average exchange rates, preceding depreciation shifts that measure back one year, and volatility summarizes three consecutive annual changes ending in the expenditure year. Construction therefore uses no later observation years. The underlying historical series nevertheless reflect the extraction vintage rather than information necessarily available at each historical decision date. All three indicators enter jointly to distinguish their partial associations. Merchandise imports determine eligibility and do not enter as an explanatory control. No moderator, mediator, interaction or additional control is constructed. The logarithmic outcome expresses relationships proportionally, while the level specification assesses absolute expenditure differences on the same principal sample. Equation 5 translates a coefficient into a percentage contrast:

$$P_k = 100\left[e^{10\beta_k} - 1\right]$$

Here, $P_k$ is the fitted percentage expenditure contrast associated with a ten unit increase in indicator k, holding the other indicators and fixed effects constant. For depreciation, the increment is ten percentage log points. For volatility, it is ten percentage points on the annual logarithmic change scale. Confidence limits are transformed using the same expression. These contrasts describe the fitted conditional relationship without assigning a causal interpretation.

**4.3 Estimation and Statistical Inference:**

Estimation uses ordinary least squares after removing economy and year fixed effects through alternating demeaning. Each iteration subtracts economy means and then year means from the outcome and explanatory variables. Iteration stops when the maximum absolute change across transformed values is below \(10^{−11}\), subject to a maximum of 10,000 iterations. The baseline converged after eight iterations, the extended logarithmic model after 12 and the expenditure level model after ten. The transformed regression is solved using the NumPy linear least squares routine without observation or population weights. The transformed explanatory matrix has rank three, confirming that each indicator retains identifiable variation after fixed effects are removed. Consequently, the estimates weight retained economy observations equally rather than represent population weighted international expenditure relationships. Standard errors use an economy clustered sandwich covariance estimator. Equation 6 specifies the implemented calculation:

$$\widehat{V} = cA^{-1}\left[\sum_{g=1}^{G} s_g\, s_g^{\top}\right]A^{-1}, \qquad A = \widetilde{X}^{\top}\widetilde{X}, \qquad s_g = \widetilde{X}_g^{\top}\hat{u}_g, \qquad c = \frac{G}{G-1}\frac{N-1}{N-K}$$

Here, $\widehat{V}$ is the estimated coefficient covariance matrix, $\widetilde{X}$is the explanatory matrix after fixed effect removal, and $\hat{u}_g$contains residuals for economy g. The vector $s_g$aggregates explanatory residual products within that economy. The symbols G, N and Kdenote the number of economies, observations and fitted parameters, respectively. The parameter count includes the fixed effect space and three explanatory coefficients, giving $K = G + T - 1 + 3$, where Tis the number of observed years. Superscript Tdenotes matrix transposition. Clustering permits heteroskedasticity and residual dependence within economies. Confidence intervals and two-sided tests use a student t distribution with $G - 1$ degrees of freedom, giving 184 degrees of freedom in the principal and extended samples. This implementation follows the clustered inference framework discussed by Cameron and Miller, 2015. It assumes sufficiently independent clusters and does not address every form of dependence between economies.

The three coefficient tests are also assessed as one comparison family using Holm adjustment. The unadjusted p values are ordered from smallest to largest, multiplied successively by three, two and one, and replaced by their cumulative maximum, capped at one. Both unadjusted and adjusted values are reported alongside point wise 95% confidence intervals. Descriptive analysis reports valid counts, means, sample standard deviations, medians and ranges. Pooled Spearman correlations summarize monotonic associations using average ranks for ties. These correlations are descriptive rather than substitutes for the conditional panel estimates. The distinction between rank based and linear association measures follows de Winter, Gosling and Potter, 2016. Computations use Python 3.12.14, NumPy 2.3.5 and SciPy 1.17.0. The procedures are deterministic and require no random seed.

**4.4 Validation, Sensitivity and Interpretive Limits:**

Validation first checks unique economy and year identifiers, analytical eligibility and agreement between linked source values and analytical records. Equations 1 to 3 are independently recalculated from source exchange rates. Baseline coefficients are additionally checked against an explicit economy and year dummy regression. The maximum coefficient difference is below $10^{-12}$, supporting numerical agreement between the two implementations. Collinearity is assessed on the explanatory variables after fixed effect removal. Variance inflation factors are calculated from the diagonal elements of the inverse explanatory cross product matrix and the corresponding column sums of squares. These targets overlap in the variation actually used for estimation rather than overlap in untransformed indicators. Model fit is summarized as one minus the residual sum of squares divided by the sum of squared expenditure deviations remaining after economy and year effects are removed.

Three exploratory sensitivity analyses address specific interpretive threats. First, extending coverage through 2024 assesses whether the sparsely represented final year changes the logarithmic estimates. Second, replacing logarithmic expenditure with expenditure levels on the identical principal sample separates functional form sensitivity from sample composition. Third, excluding each of the 185 economies in turn assesses whether coefficient direction and magnitude depend on a single economy. Each exclusion requires renewed fixed effect removal and estimation. Missing observations are handled through the documented complete observation rules. No imputation, interpolation, winsorization or trimming is applied. Extreme reported currency changes remain in the analysis. The exclusion checks assess sensitivity to individual economies without establishing that extreme observations represent valid economic changes rather than reporting or currency discontinuities. The analysis is exploratory, with no documented preregistration. Sensitivity checks are not presented as prespecified confirmatory tests. Conclusions depend on estimated magnitudes, confidence intervals, comparison adjustments and specification sensitivity rather than a significance threshold alone, consistent with Wasserstein and Lazar, 2016. The resulting method supports reproducible conditional association estimates while retaining limits arising from historical revisions, incomplete coverage, omitted changing conditions and dependence between economies.

**5. Findings:**

This analysis examines how annual depreciation, preceding depreciation and rolling currency volatility relate to health expenditure per capital. The findings distinguish pooled associations from relationships estimated within economies after accounting for common year differences. Sensitivity analyses assess whether conclusions depend on final year coverage, expenditure scaling or individual economies.

**5.1 Sample Characteristics And Observed Variation:**

The principal estimation sample contains 1,995 annual observations across 185 economies from 2013 to 2023. The panel is unbalanced, with annual coverage ranging from 178 to 183 economies. The extended sample adds 22 observations from 2024, producing 2,017 observations across the same 185 economies. Restricting the principal estimates to 2023 avoids allowing the limited geographical coverage of the final year to define the baseline results.

Table 4: Descriptive statistics for the principal estimation sample

| Indicator | Observations | Mean | Standard Deviation | Median | Minimum | Maximum |
|---|---|---|---|---|---|---|
| Health expenditure per capita | 1,995 | 1,565.19 | 1,955.15 | 803.81 | 25.41 | 13,473.19 |
| Annual currency depreciation | 1,995 | 4.50 | 14.60 | 0.44 | −204.66 | 223.63 |
| Preceding currency depreciation | 1,995 | 4.79 | 15.94 | 0.87 | −105.95 | 476.80 |
| Rolling exchange rate volatility | 1,995 | 6.65 | 12.42 | 4.84 | 0.00 | 266.20 |

Health expenditure is expressed in current international dollars per person at purchasing power parity. Depreciation is expressed in percentage log points, while volatility measures the sample standard deviation of three annual depreciation observations. Source: calculations from the supplied workbook. Health expenditure exhibits substantial dispersion, with its mean almost twice its median. The logarithmic outcome specification therefore examines proportional expenditure differences, while an alternative specification retains expenditure in international dollars. These specifications answer different magnitude questions. Neither converts financial expenditure into a direct measure of service provision. Currency distributions also contain substantial asymmetry and extreme observations. Annual depreciation averages 4.50 percentage log points, compared with a median of 0.44. Rolling volatility equals zero in 296 observations. These features make the distinction between pooled distributional patterns and conditional relationships within economies consequential.

**5.2 Associations Addressing the Research Questions:**

The exploratory baseline jointly includes all three exchange rate indicators, economy fixed effects and year fixed effects, with the natural logarithm of health expenditure as the outcome. Economy effects absorb persistent differences across economies, while year effects absorb common annual shifts. No additional controls are included. Standard errors are clustered across 185 economies, with a finite sample correction and inference based on 184 degrees of freedom. This permits residual dependence within economies, following the framework discussed by Cameron and Miller, 2015, but does not eliminate dependence between economies.

Table 5: Joint associations with logarithmic health expenditure

| Exchange Rate Indicator | Coefficient | Clustered Standard Error | Lower 95% Confidence Limit | Upper 95% Confidence Limit | pValue | Holm Adjusted p Value |
|---|---|---|---|---|---|---|
| Annual depreciation | −0.001397 | 0.000483 | −0.002350 | −0.000443 | 0.0043 | 0.0130 |
| Preceding depreciation | −0.000806 | 0.000534 | −0.001861 | 0.000248 | 0.1331 | 0.1331 |
| Rolling volatility | −0.001971 | 0.000923 | −0.003791 | −0.000151 | 0.0340 | 0.0680 |

The model uses 1,995 observations across 185 economies during 2013 to 2023. All indicators enter jointly with economy and year fixed effects. Confidence intervals are point wise rather than simultaneous. Holm adjustment treats the three coefficient tests as one comparison family. Source: calculations from the supplied workbook. For RQ1, annual depreciation has a negative conditional association with health expenditure. A ten-percentage log point increase corresponds to approximately 1.39% lower expenditure, with a point wise 95% confidence interval from 2.32% lower to 0.44% lower. The association remains distinguishable from zero after adjustment for the three comparisons. This result concerns expenditure differences within economies after removing common year shifts. The direction is consistent with purchasing pressure associated with currency depreciation. Gopinath and colleagues, 2020, establish the relevance of dominant currency invoicing for international price transmission. However, the present estimates do not measure invoicing arrangements or imported health inputs and therefore do not establish that mechanism as the explanation for the observed association.

For RQ2, preceding depreciation has a smaller and less precise conditional association. A ten-percentage log point increase corresponds to approximately 0.80% lower current expenditure, but its confidence interval extends from 1.84% lower to 0.25% higher. The evidence therefore does not establish an additional lagged association once current depreciation; volatility and fixed effects enter jointly. The interval remains compatible with a modest negative relationship and should not be interpreted as demonstrating that delayed adjustment is absent. For RQ3, greater rolling volatility has a negative association with logarithmic expenditure. A ten-percentage point increase corresponds to approximately 1.95% lower expenditure, with a point wise confidence interval from 3.72% lower to 0.15% lower. Its unadjusted p value is 0.0340, increasing to 0.0680 after adjustment for the three comparisons. The evidence is consequently more tentative than the contemporaneous depreciation result. Bloom, 2014, explains how uncertainty can influence expenditure timing and adjustment behaviour. The negative volatility estimate is compatible with such reasoning, but realised currency variability does not directly measure uncertainty or purchasing decisions. The result identifies a conditional expenditure pattern rather than a verified behavioural channel. Pooled Spearman correlations provide a different perspective. Health expenditure correlates negatively with current depreciation at −0.189 and preceding depreciation at −0.155, while its correlation with volatility is approximately zero at 0.011. The contrast between the pooled volatility correlation and its negative conditional coefficient indicates that the relationship depends on separating persistent economy differences and common year variation. These pooled correlations remain descriptive and do not carry independent causal interpretations.

**5.3 Sensitivity and Estimation Credibility:**

Adding the 22 observations from 2024 leaves the logarithmic estimates nearly unchanged. The coefficient for annual depreciation changes from −0.001397 to −0.001388, preceding depreciation from −0.000806 to −0.000805, and volatility from −0.001971 to −0.001979. The principal patterns therefore do not depend on excluding the sparsely represented final year.

Table 6: Sensitivity to sample coverage and expenditure scaling

| Indicator | Logarithmic Outcome, 2013 to 2023 | Logarithmic Outcome, 2013 to 2024 | Expenditure Level Outcome, 2013 to 2023 | Lower 95% Confidence Limit for Level Coefficient | Upper 95% Confidence Limit for Level Coefficient |
|---|---|---|---|---|---|
| Annual depreciation | −0.001397 | −0.001388 | −1.595 | −3.267 | 0.077 |
| Preceding depreciation | −0.000806 | −0.000805 | 0.216 | −1.041 | 1.473 |
| Rolling volatility | −0.001971 | −0.001979 | −2.282 | −5.352 | 0.788 |
| Observations | 1,995 | 2,017 | 1,995 | Not applicable | Not applicable |

All specifications jointly include the three exchange rate indicators and economy and year fixed effects. Level coefficients measure international dollars per person for a one unit increase in the corresponding indicator. Source: calculations from the supplied workbook. Changing the outcome from logarithmic expenditure to expenditure levels weakens the evidence. Current depreciation and volatility retain negative coefficients, but both confidence intervals include zero. The preceding depreciation coefficient becomes positive and remains imprecise. The findings therefore provide stronger evidence for proportional expenditure associations than for a common absolute expenditure difference across economies. This distinction matters because expenditure levels vary substantially across the sample. Fan and Savedoff, 2014, associate international health expenditure patterns with financing structures, income and cost pressures. The difference between logarithmic and level estimates is consistent with heterogeneity in spending scale, although the present analysis does not isolate its determinants. Removing each economy in turn preserves the negative direction of all three logarithmic coefficients. Annual depreciation coefficients range from −0.001522 to −0.001078, preceding depreciation from −0.001655 to −0.000433, and volatility from −0.003487 to −0.001595. Directional stability therefore does not depend on a single economy, although the volatility magnitude varies across exclusions. These are exploratory sensitivity checks rather than prespecified tests.

Variance inflation factors for the jointly entered indicators range from 1.05 to 1.33 after removing economy and year effects. Their mathematical overlap does not produce substantial linear redundancy in this specification. Nevertheless, the indicators explain only 5.79% of the expenditure variation remaining after those effects are removed. The model captures a limited component of expenditure variation. Interpretation rests on magnitude, precision and sensitivity rather than significance alone, consistent with Wasserstein and Lazar, 2016. The estimates do not account for changing domestic financing conditions, health needs or other omitted influences. Common year effects and economy clustering also do not establish independence between economies or resolve endogeneity. The evidence answers the three research questions unevenly. Current depreciation exhibits the clearest negative proportional association with expenditure. Preceding depreciation does not show a precisely estimated additional relationship. Volatility exhibits a negative conditional pattern whose evidential strength depends on multiplicity adjustment and expenditure scaling. These conclusions describe associations in the observed panel and do not establish reductions in service availability or causal effects of currency movements.

**6. Discussion:**

Currency depreciation matters for health financing, but its interpretation depends on whether expenditure differences are examined across economies or within them. Table 5 identifies a negative association between contemporaneous depreciation, constructed through Equation 1, and proportional health expenditure after accounting for persistent economy differences and common year shifts. The contribution is the distinction between this contemporaneous relationship, the imprecise preceding depreciation estimates and the more tentative volatility association. These results qualify a single, uniform account of currency exposure. Forbes, Hjortsoe and Nenova, 2018, demonstrate that exchange rate transmission depends on the shocks generating currency movements. The present analysis extends that interpretive caution to health expenditure: an observed currency change carries information about spending patterns without identifying its underlying shock or transmission mechanism. The temporal comparison sharpens what can be inferred about adjustment. Depreciation in the preceding year, defined through Equation 2, does not exhibit a precisely estimated additional relationship after contemporaneous depreciation and volatility enter jointly in Table 5. This finding limits claims that earlier currency movements necessarily generate a persistent expenditure response. It does not establish that adjustment occurs immediately or that delayed responses are absent. Imai, Keele and Tingley, 2010, distinguish the identification of causal mediation from the estimation of relationships among observed variables. That distinction is consequential here: the coefficients cannot separate procurement costs, budget adjustments or purchasing decisions. The contribution is therefore a clearer temporal boundary around the observed association, rather than evidence of a newly identified mediation pathway.

Currency variability contributes a different theoretical signal from currency direction. The near zero pooled volatility correlation contrasts with the negative conditional estimate in Table 5, indicating that an aggregate comparison can obscure the relationship obtained after removing persistent economy differences and common annual shifts. However, the volatility measure in Equation 3 incorporates depreciation observations already represented elsewhere in the model. Its coefficient cannot be interpreted as a separate causal channel or converted into a share of a total effect. Moreover, adjustment for the three comparisons weakens its evidential strength. Boz and colleagues, 2022, document international variation in trade invoicing arrangements, reinforcing the importance of distinguishing observed currency movements from actual transaction exposure. The analytical advance is to separate direction, timing and variability without assuming that they represent independent transmission mechanisms. Measurement scale changes the substantive conclusion. Table 6 shows that the negative contemporaneous and volatility coefficients persist in direction when expenditure remains in international dollars, but their confidence intervals include zero. Combined with the expenditure dispersion in Table 4, this indicates stronger evidence for proportional spending differences than for a common absolute spending difference across economies. Stability after adding the sparse final year does not remove

this dependence on outcome scaling. Kutzin, 2013, distinguishes health financing arrangements from broader health system performance objectives. The present findings make that distinction operational: lower proportional expenditure cannot independently establish reduced access, poorer financial protection or fewer services. The contribution is a measurement sensitive interpretation of currency exposure that prevents financial associations from becoming unsupported claims about health system outcomes.

The international relevance lies in connecting currency conditions with expenditure adjustment across a geographically broad panel while preserving differences in financing scale. Lu and colleagues, 2010, examine public health financing in developing countries through fiscal resources and external assistance. The present analysis addresses a different relationship by examining total expenditure per person alongside currency dynamics; it does not establish contrasting responses between advanced and emerging economies because those subgroup differences were not estimated. Table 6 and the economy exclusion checks instead show that geographical breadth and directional stability can coexist with specification dependent precision. For decision makers, the evidence supports monitoring proportional health expenditure alongside contemporaneous currency movements, while avoiding uniform expenditure rules derived from these coefficients. The theoretical implication is that currency exposure should enter health financing analysis as a differentiated, conditional association rather than a sufficient explanation of spending adjustment.

**7. Conclusion and Implications:**

Global health financing requires an understanding of external financial pressures that distinguishes immediate adjustment from persistence and instability. This analysis shows that these dimensions carry different information: the contemporaneous relationship is clearer, the preceding relationship remains imprecise, and the variability relationship depends more strongly on analytical choices. Their joint assessment contributes an international empirical perspective that separates proportional adjustment from absolute spending differences. The theoretical contribution is to qualify uniform transmission narratives: external financial conditions accompany expenditure patterns through relationships whose interpretation depends on timing, measurement scale and persistent differences across economies. These associations do not establish causal pathways or institutional mechanisms. For decision makers, the evidence supports incorporating external financial conditions into expenditure surveillance while assessing proportional and monetary changes together. Budget reviews should distinguish changes in financial allocations from changes in purchasing capacity and service provision. Operational monitoring can pair currency information with expenditure records to identify periods requiring closer investigation, rather than trigger automatic budget adjustments. Policy applications should remain conditional on domestic financing arrangements and verified purchasing exposure. The broader social relevance lies in improving the evidence used to assess financing pressures without equating spending changes with changes in access, protection or health system performance.

Further inquiry can strengthen identification through archived data vintages, longer observation histories and direct measures of purchasing exposure. Linking expenditure records with procurement prices, quantities and financing arrangements would permit explicit assessment of transmission mechanisms. Designs using plausibly external currency shocks could distinguish causal responses from concurrent economic changes. Comparative analyses across financing systems could examine whether institutional arrangements alter adjustment patterns. More complete geographical coverage and consistent price measures would also clarify the sensitivity of international comparisons. These extensions would test the transferability of the observed relationships while preserving the distinction between financial expenditure and the services it supports.

**References:**

1. Amiti, M., Itskhoki, O., & Konings, J. 2014. Importers, exporters, and exchange rate disconnect. American Economic Review, 104, issue 7, 1942 to 1978. https://doi.org/10.1257/aer.104.7.1942
2. Bloom, N. 2014. Fluctuations in uncertainty. Journal of Economic Perspectives, 28, issue 2, 153 to 176. https://doi.org/10.1257/jep.28.2.153
3. Boz, E., Casas, C., Georgiadis, G., Gopinath, G., Le Mezo, H., Mehl, A., & Nguyen, T. 2022. Patterns of invoicing currency in global trade: New evidence. Journal of International Economics, 136, Article 103604. https://doi.org/10.1016/j.jinteco.2022.103604
4. Cameron, A. C., & Miller, D. L. 2015. A practitioner's guide to cluster robust inference. Journal of Human Resources, 50, issue 2, 317 to 372. https://doi.org/10.3368/jhr.50.2.317
5. de Winter, J. C. F., Gosling, S. D., & Potter, J. 2016. Comparing the Pearson and Spearman correlation coefficients across distributions and sample sizes: A tutorial using simulations and empirical data. Psychological Methods, 21, issue 3, 273 to 290. https://doi.org/10.1037/met0000079
6. Fan, V. Y., & Savedoff, W. D. 2014. The health financing transition: A conceptual framework and empirical evidence. Social Science & Medicine, 105, 112 to 121. https://doi.org/10.1016/j.socscimed.2014.01.014
7. Forbes, K., Hjortsoe, I., & Nenova, T. 2018. The shocks matter: Improving our estimates of exchange rate pass through. Journal of International Economics, 114, 255 to 275. https://doi.org/10.1016/j.jinteco.2018.07.005
8. Gopinath, G., Boz, E., Casas, C., Díez, F. J., Gourinchas, P. O., & Plagborg-Møller, M. 2020. Dominant currency paradigm. American Economic Review, 110, issue 3, 677 to 719. https://doi.org/10.1257/aer.20171201
9. Hughes, R. A., Heron, J., Sterne, J. A. C., & Tilling, K. 2019. Accounting for missing data in statistical analyses: Multiple imputation is not always the answer. International Journal of Epidemiology, 48, issue 4, 1294 to 1304. https://doi.org/10.1093/ije/dyz032
10. Imai, K., Keele, L., & Tingley, D. 2010. A general approach to causal mediation analysis. Psychological Methods, 15, issue 4, 309 to 334. https://doi.org/10.1037/a0020761
11. Kutzin, J. 2013. Health financing for universal coverage and health system performance: Concepts and implications for policy. Bulletin of the World Health Organization, 91, issue 8, 602 to 611. https://doi.org/10.2471/BLT.12.113985

12. Lu, C., Schneider, M. T., Gubbins, P., Leach-Kemon, K., Jamison, D., & Murray, C. J. L. 2010. Public financing of health in developing countries: A cross national systematic analysis. The Lancet, 375, issue 9723, 1375 to 1387. https://doi.org/10.1016/S0140-6736(10)60233-4
13. Reeves, A., McKee, M., Basu, S., & Stuckler, D. 2014. The political economy of austerity and healthcare: Cross national analysis of expenditure changes in 27 European nations 1995 to 2011. Health Policy, 115, issue 1, 1 to 8. https://doi.org/10.1016/j.healthpol.2013.11.008
14. Sandve, G. K., Nekrutenko, A., Taylor, J., & Hovig, E. 2013. Ten simple rules for reproducible computational research. PLOS Computational Biology, 9, issue 10, Article e1003285. https://doi.org/10.1371/journal.pcbi.1003285
15. Wasserstein, R. L., & Lazar, N. A. 2016. The ASA's statement on p values: Context, process, and purpose. The American Statistician, 70, issue 2, 129 to 133. https://doi.org/10.1080/00031305.2016.1154108
16. World Bank. n.d.-a. Current health expenditure per capita, PPP, current international dollars. World Development Indicators. https://data.worldbank.org/indicator/SH.XPD.CHEX.PP.CD
17. World Bank. n.d.-b. Merchandise imports, current United States dollars. World Development Indicators. https://data.worldbank.org/indicator/TM.VAL.MRCH.CD.WT
18. World Bank. n.d.-c. Official exchange rate, domestic currency units per United States dollar, period average. World Development Indicators. https://data.worldbank.org/indicator/PA.NUS.FCRF