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A Cross-Country Study Between Per Capita Pharmaceutical Expenditure and Life Expectancy

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Abstract. This study quantified the cross-country association between per capita pharmaceutical expenditure and life expectancy, examining how macroeconomic and healthcare system factors modify this relationship. Cross-sectional data from 42 countries (OECD, WHO, World Bank, plus China and India) were analysed using 2019–2021 country-level averages. Stepwise OLS regression progressively adjusted for physician density, urbanisation, geographic region, and per capita GDP. Pharmaceutical expenditure showed a significant positive coefficient in the unadjusted model (β=3.50, P=0.001), but this became non-significant after full adjustment (β=−1.51, P=0.183). Sensitivity analyses confirmed the absence of an independent association, suggesting the crude correlation reflects underlying disparities in national wealth and healthcare infrastructure rather than a direct causal link.

Keyword: retail pharmaceutical expenditure, life expectancy, cross-national comparison, ecological study, national income

1. Introduction

Medicines represent a critical input for clinical disease management and constitute a major component of healthcare spending [1]. However, total monetary spending cannot be equated with actual drug volumes consumed [2]: higher expenditure may reflect broader access, but also higher prices, different prescribing behaviours, or supply-chain markups. Life expectancy at birth offers a composite snapshot of population-wide mortality patterns [3], widely adopted for cross-national comparisons. Economic advancement typically correlates with public infrastructure, education, nutrition, and expanded healthcare resources.

This study addresses three questions: (1) what distributional forms per capita pharmaceutical spending and life expectancy take; (2) whether a crude unadjusted correlation exists; and (3) how the regression coefficient shifts as physician density, urbanisation, geographic region, and per capita GDP are sequentially incorporated. The study offers both a methodological caveat and an evidentiary basis for health policy decision-making.

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2. Material and methods

This ecological cross sectional study uses individual countries as the unit of analysis. The initial pharmaceutical spending dataset covered 44 OECD member states and territories; Colombia, New Zealand and Turkey lacked complete records within the 2019-2021 window, while Luxembourg had missing physician density metrics and was excluded from the main regression modelling. After that, China and India were folded into the sample, so the final set became 42 countries: 30 European, 4 Asian, 4 Latin American, and 4 nations from other parts of the world.

Life expectancy data were sourced from WHO [3]; per capita GDP [4], physician density [5], and urbanization rate from World Bank databases [6]; pharmaceutical expenditure from OECD [2] (PPP USD), supplemented by domestic NHA data for China [7, 8] and India [9]. Three-year arithmetic means (2019-2021) were computed when data were available. Due to definitional mismatches between Chinese/Indian and OECD accounting, sensitivity models excluding these two economies were pre-specified.

Table 1. Research variables, measurement calibers and data sources

Role	Variables	Measurement	Sources
Dependent (Y)	Life expectancy at birth	Annual average 2019–2021	WHO/OWID
Core X	Per capita pharma. expenditure	Mean value, USD PPP per capita	OECD; NHA
Control	Per capita GDP	Average 2019–2021, USD PPP	WDI
Control	Physician density	Average, per 1,000 people	WDI
Control	Urbanisation rate	Average 2019–2021, %	WDI
Grouping	Region	Europe, Asia, Latin Am., Others	By country

Due to pronounced right skew, pharmaceutical expenditure and GDP were natural log transformed. Four sequential OLS models: M0 (unadjusted), M1 (+physician density, urbanisation), M2 (+region), M3 (+ln GDP). The full adjusted equation:

$$LE_i=\beta_0+\beta_1\ln(Pharma_i)+\beta_2 Doctor_i+\beta_3 Urban_i+\gamma Region_i+\beta_4\ln(GDP_i)+\varepsilon_i \quad (1)$$

Where:

LE_i = life expectancy at birth for country i; $Pharma_i$ = per capita retail pharmaceutical expenditure of country i; $Doctor_i$ = physician density (per 1,000 population) in country i; $Urban_i$ = urban population percentage of country i; $Region_i$ = categorical indicator of country geographic region; GDP_i = per capita PPP GDP of country i; ε_i = stochastic error term; All statistical analyses were performed using R [10].

3. Data analysis

3.1. Data overview

All five core indicators are continuous; region is categorical. European nations account for 71.4% of the sample. Among 40 OECD economies, 35 had complete three-year pharmaceutical records; Australia, Israel, Japan and Malta had two valid years; Brazil had one year. China and India estimates came from domestic health accounting.

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3.2. Data quality

Limitations stem from comparability issues (single-year data for Brazil/Japan, NHA-OECD mismatches for China/India, COVID-19 overlap). Outliers (US, India, Japan) were retained; log transformation, Cook's distance, and leave-one-country-out analyses addressed leverage.

3.3. Univariate description

Descriptive statistics for all continuous variables are shown in Table 2. Both distributions are right-skewed; log transformation mitigates scale dominance.

Table 2. Descriptive statistics of main continuous variables (n=42)

Variable	Mean	SD	Median	Min	Max
Life Expectancy (Years)	79.51	3.56	80.94	69.41	84.53
Pharma expenditure (USD PPP)	569.40	224.33	553.08	80.00	1341.52
ln(Pharma expenditure)	6.25	0.49	6.32	4.38	7.20
GDP per capita (USD PPP)	46085.59	18146.75	44649.73	7176.71	102140.87
ln(per capita GDP)	10.65	0.47	10.71	8.88	11.53
Physician density (per 1,000)	3.62	0.98	3.58	0.81	6.24
Urbanisation Rate (%)	75.20	13.45	78.48	34.13	95.21

3.4. Inter-group comparison

Life expectancy rises stepwise across GDP tertiles, with diminishing gains at higher income levels (Table 3). The increase from the middle group to the high group is smaller than that from the low group to the middle group, which is consistent with the existing understanding that the relationship between income and life expectancy may tend to plateau [3].

Other indicators also rise with GDP, but substantial within-group variation persists (Table 3).

Table 3. Overview of indicators grouped by tertiles of per capita GDP

Group	N	GDP Range	Life exp. (yrs)	Pharma exp.	Phys. density	Urban (%)
Low	14	7176.71–37496.65	76.16±3.42	427.14±193.48	3.32±1.38	67.35±14.96
Middle	14	38010.42–52028.31	80.74±2.76	604.99±150.23	3.41±0.68	74.97±10.88
High	14	52729.46–102140.87	81.63±1.44	676.07±251.59	4.13±0.53	83.29±9.55

3.5. Relationships between variables

All variables are positively correlated; pharmaceutical expenditure and GDP show the strongest link (r=0.73), indicating shared developmental gradients (Table 4).

Table 4. Pearson correlation matrix of main analyzed variables (n=42)

Variable	Life exp.	ln drug	ln GDP	Phys.	Urban
Life expectancy	1.00	0.48	0.73	0.37	0.58
ln drug expenditure	0.48	1.00	0.73	0.52	0.33

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Table 4. (continued)

ln per capita GDP	0.73	0.73	1.00	0.55	0.45
Physician density	0.37	0.52	0.55	1.00	0.20
Urbanisation rate	0.58	0.33	0.45	0.20	1.00

3.6. Key findings and implications for modeling

Three conclusions guide modeling: log transformation suits the skewed expenditure distribution; pharmaceutical expenditure and GDP are strongly correlated (r=0.73), complicating unadjusted interpretation; and life expectancy differences across GDP groups with overlapping pharmaceutical expenditure support a stepwise approach.

4. Regression and robustness analysis results

4.1. Main regression results

The coefficient declines progressively from M0 to M3, losing significance after M1, with adjusted R^2 rising to 0.638 (Table 5, Figure 2). The coefficient crosses zero after M1 and reverses direction, confirming no stable independent positive association.

Table 5. Stepwise regression results of per capita retail pharmaceutical expenditure and life expectancy (n=42)

Model	Adjusted variables	β	SE	95% CI	P	Adj.R^2
M0	None	3.50	1.01	1.46–5.55	0.001	0.211
M1	Physician density, urbanisation	1.81	1.07	-0.36–3.99	0.099	0.400
M2	M1 + Region	0.67	1.28	-1.92–3.26	0.602	0.423
M3	M2 + ln(per capita GDP)	-1.51	1.11	-3.78–0.75	0.183	0.638

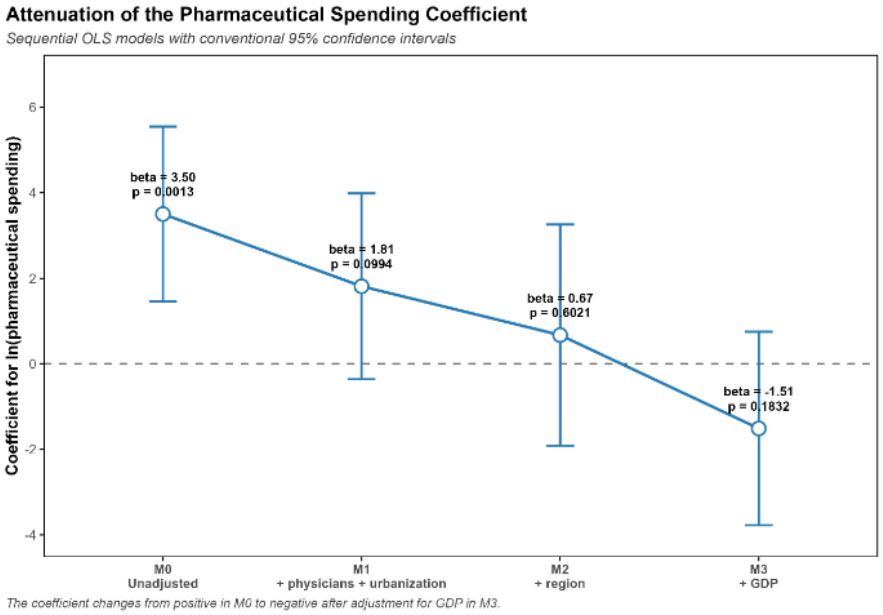


Figure 1. Changes in the drug expenditure coefficient during the gradual adjustment process

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4.2. Subgroup analysis

Subgroup coefficients vary considerably; non-European and low physician density groups reach nominal significance (Table 6, Figure 2). However, subgroups include only 12–21 countries with multiple parameters and comparisons. These results can only generate hypotheses and cannot confirm genuine effect modification.

Table 6. Results of exploratory subgroup analysis

Subgroup	N	M0 β (P)	M3 β (P)	Adj.R^2
Full sample	42	3.50 (0.001)	-1.51 (0.183)	0.638
Bottom third GDP	14	1.94 (0.213)	-4.67 (0.071)	0.475
Middle third GDP	14	4.84 (0.126)	1.87 (0.589)	0.266
Top third GDP	14	-2.43 (0.034)	-2.13 (0.101)	0.133
Europe	30	2.06 (0.426)	0.03 (0.986)	0.515
Non-European	12	3.87 (0.020)	-5.41 (0.044)	0.819
Low urbanisation (≤78.5%)	21	2.81 (0.051)	-1.64 (0.604)	0.498
High urbanisation (>78.5%)	21	3.24 (0.034)	-0.87 (0.590)	0.595
Low physician density (≤3.58)	21	3.56 (0.009)	-4.39 (0.035)	0.706
High physician density (>3.58)	21	0.24 (0.930)	-0.74 (0.722)	0.452

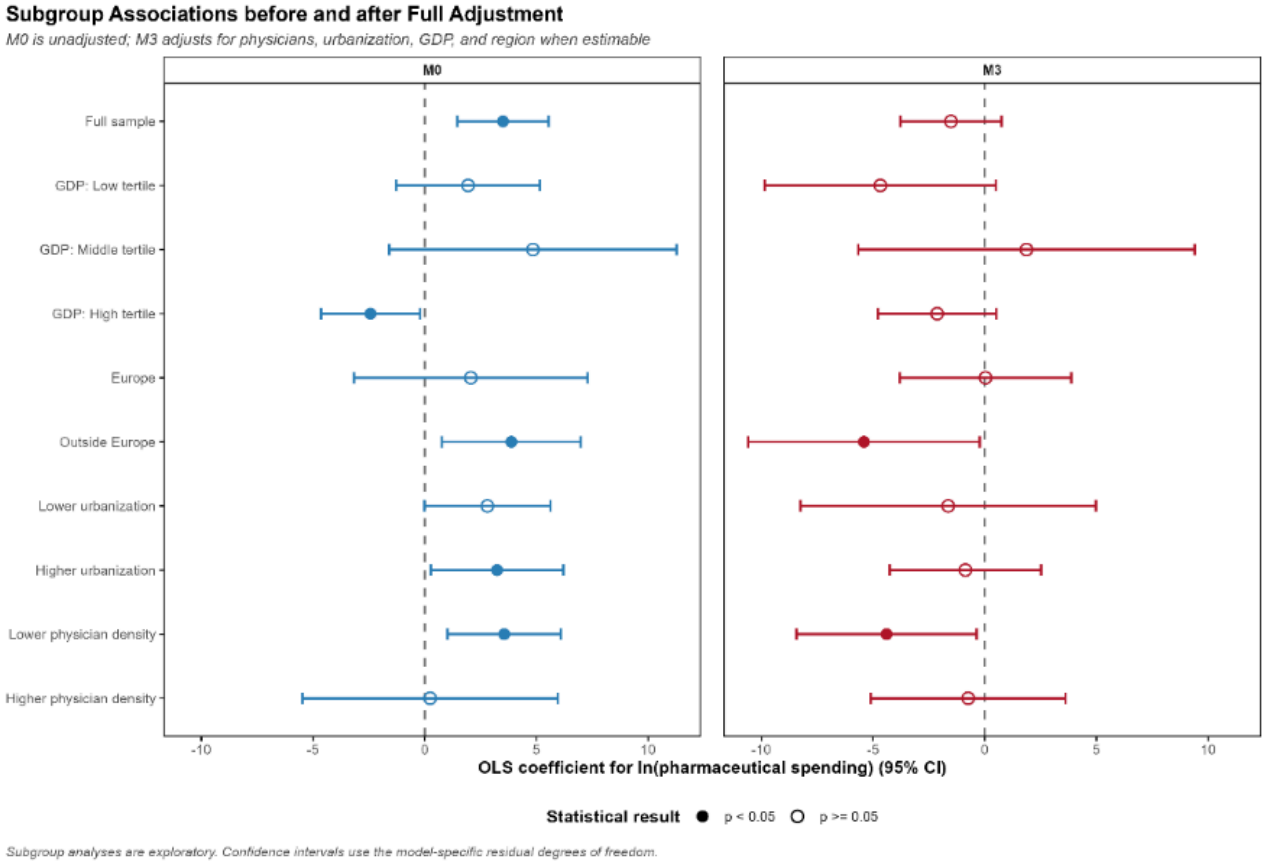


Figure 2. Unadjusted and fully adjusted drug expenditure coefficients within subgroups

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4.3. Sensitivity analysis

All exclusion scenarios yield non-significant M3 coefficients with confidence intervals crossing zero (Table 7). The coefficient remains non-significant across all exclusion scenarios, confirming robustness. Excluding China and India raises M0's P-value to 0.078.

Table 7. Sensitivity analysis of predefined country exclusions

Scenario	N	M0 β (95% CI)	M0 P	M3 β (95% CI)	M3 P
Main sample	42	3.50 (1.46–5.55)	0.001	-1.51 (-3.78–0.75)	0.183
Exclude USA	41	4.11 (2.03–6.19)	<0.001	-0.72 (-2.92–1.49)	0.514
Exclude China & India	40	2.32 (-0.27–4.90)	0.078	-2.27 (-5.12–0.58)	0.114
Exclude USA, China & India	39	3.12 (0.39–5.85)	0.026	-0.89 (-3.87–2.09)	0.546

5. Discussion

This cross-national ecological analysis found a crude positive association between per capita pharmaceutical expenditure and life expectancy, but this disappeared after controlling for physician density, urbanisation, region, and GDP [1]. The correlation matrix showed pharmaceutical expenditure and GDP are highly correlated (r=0.73), with GDP showing the same correlation with life expectancy, reflecting national development gradients rather than an independent causal effect. Although the fully adjusted coefficient was negative, its confidence interval crossed zero. The retail pharmaceutical expenditure metric encompasses drug prices, sales volumes, and profit margins, yet excludes inpatient pharmaceuticals [2]; the same expenditure corresponds to vastly different medication quantities across countries, making it unable to measure healthcare system efficiency.

6. Conclusions

This study, based on cross-sectional data from 42 countries for 2019-2021 and stepwise OLS regression, examined the cross-national association between per capita retail pharmaceutical expenditure and life expectancy at birth, and assessed how macroeconomic and healthcare system factires modify this relationship. The unadjusted bivariate regression showed a signidicant positive association (β=3.50, P=0.001); however, after sequentially controlling for physician density, urbanisation rate, geographic region, and per capita GDP, the coefficient declined progressively and lost statistical significance after Model M1, with the fully adjusted M3 coefficient turning negative and non-significant (β=-1.51, P=0.183). the correlation matrix further revealed that log pharmaceutical expenditure and log per capita GDP are highly correlated (r=0.73), with per capita GDP showing an identical correlation with life expectancy(r=0.73), indicating that both lie on a shared development gradient. In subgroup analysis, the non-European and low physician density subgroups reached nominal significance for M3 coefficients, bit due to small sample sizes and multiple comparison issues, these findings are only preliminary. Sensitivity analyses excluding the Unites States, China, and Inida confirmed that all M3 confidence intervals crossed zero, further establishing the absence of an independent statistical association between pharmaceutical expenditure and life expectancy. The core conclusion is that the crude correlation between per capita pharmaceutical expenditure and life expectancy primarily reflects cross-national differences in economic development and healthcare infrastructure, rather than an independent causal effect for pharmaceutical spending on population longevity. This finding suggests that policymarkers should

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exercise caution when interpreting cross-national associations between pharmaceutical expenditure and health indicators, and avoid equating ecological-level correlations with causal relationships.

This study has several limitations. The ecological design precludes extrapolating national-level findings to individuals; cross-sectional data combined with the pandemic-confounded observation window limits causal inferences; and social determinants such as education and income inequality were not incorporated into the model, potentially leaving residual confounding. Future research should adopt longitudinal designs and incorporate between pharmaceutical expenditure and population health.

References

[1] Li, H. Y., & Zhang, R. X. (2024). Analysis of the structure and trend prediction of China's total health expenditure. *Frontiers in Public Health, 12*, 1425716. https://doi.org/10.3389/fpubh.2024.1425716

[2] Organisation for Economic Co-operation and Development. (2026). Pharmaceutical spending [Data set]. https://www.oecd.org/en/data/indicators/pharmaceutical-spending.html

[3] World Health Organization. (2026). Life expectancy at birth [Data set]. *Our World in Data*. https://ourworldindata.org/grapher/life-expectancy-at-birth-who-gho

[4] World Bank. (2026). GDP per capita, PPP (current international $) [Data set]. https://data.worldbank.org/indicator/NY.GDP.PCAP.PP.CD

[5] World Bank. (2026). Physicians (per 1,000 people) [Data set]. https://data.worldbank.org/indicator/SH.MED.PHYS.ZS

[6] World Bank. (2026). Urban population (% of total population) [Data set]. https://data.worldbank.org/indicator/SP.URB.TOTL.IN.ZS

[7] National Health Commission of the People's Republic of China. (2020, June 6). 2019 statistical bulletin on the development of health care in China [Data set].

[8] National Health Commission of the People's Republic of China. (2021, July 13). 2020 statistical bulletin on the development of health care in China [Data set].

[9] National Health Systems Resource Centre. (2024). National health accounts estimates for India 2021-22 (Report). https://www.nhsrcindia.org/sites/default/files/2024-09/NHA%202021-22.pdf

[10] R Core Team. (2025). *R: A language and environment for statistical computing* (Version 4.5.0) [Computer software]. R Foundation for Statistical Computing. https://www.R-project.org/