

Health expenditure and economic impact for 111 countries

Extending the 2019 WHO EPIC projection model

Jeremy A. Lauer

Unexia Association

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Abstract

Background. Decisions about health investment require evidence on health outcomes, the costs of health programmes, and all downstream outputs including potential gains in gross domestic product (GDP). This study extends to a broader country group the production framework developed in work informing the 2018 World Health Organization (WHO) Investment Case and a published 2019 ten-country analysis estimating the GDP gains resulting from reaching Universal Health Coverage. A companion paper to this one presents an audit and reassessment of the 2019 implementation. The present study addresses the question of how a common spending-to-health response might change GDP across a wider set of countries.

Methods. Simulations were attempted for the 67 countries included in a published WHO resource-needs analysis, 26 additional low-income and lower-middle-income economies, and 21 data-ready upper-middle-income economies under the World Bank fiscal-year 2027 classification. The mortality response, calculated from published programme-specific costs and postbirth deaths averted, was 88.712 deaths per additional million 2014 US dollars. Direct disability benefits were anchored to an archived ten-country reconstruction of the WHO Economic Projections for Illness and Cost of Treatment (EPIC) framework at 292.507 years lived with disability averted per million dollars. Responses were assumed to be linear and constrained by countries' burden ceilings. All 101 countries (54 original + 47 additional) received a sustained annual spending increment equal to 10% of baseline health expenditure for five years, with the full increment assigned to the six-category programme envelope studied in the 2017 resource needs analysis; however, the ten reconstructed countries from the published 2019 economic-impact analysis retained their archived spending paths. Shared health-system costs were excluded. Six of the 26 additional low-income and lower-middle-income economies required imputed capital inputs.

Results. Simulations were completed for 64 of 67 countries from the published resource-needs analysis and 47 additional economies, for a total of 111 country simulations. Five-year additional GDP was \$630.92 billion against \$460.065 billion of additional spending in the first group and \$86.097 billion against \$54.356 billion in the harmonised additional-country extension. The corresponding gains were 0.3768% and 1.1977% of cumulative baseline GDP. Across all 111 completed scenarios, additional GDP was \$717.017 billion against \$514.421 billion of spending. Twelve countries reached eligible mortality ceilings; none reached its disability ceiling. Three economies from the resource-needs analysis in 2017 were excluded because required inputs were unavailable.

Conclusions. The scenarios indicate positive production effects under the specified assumptions, but do not strongly suggest fiscal self-financing in any arbitrary country or country group. Results remain conditional on programme-only costs, transported health responses, assumed disability-to-labour conversion and simplified macroeconomic dynamics.

1 Introduction

Progress towards Universal Health Coverage remains incomplete and uneven. The 2025 global monitoring report estimated that 4.6 billion people lacked access to essential health services in 2023 and that 2.1 billion people experienced financial hardship from out-of-pocket health spending in 2022 [1]. The WHO Council on the Economics of Health for All has argued that health should be treated as a public-policy objective and an investment in social and economic value, rather than only as a cost [2].

This study continues a stream of economic work undertaken for the first-ever WHO Investment Case published in 2018 and its supporting technical analysis [3,4]. That work combined health-impact and resource-needs projections from the OneHealth Tool with the WHO Economic Projections for Illness and Cost of Treatment (EPIC) framework [5,6]. A related 2019 working paper applied the framework to ten low-income and middle-income countries [7]. A companion audit examines the source mappings, capital valuation, calibration and numerical claims in that 2019 analysis [8]. The present paper uses the corrected and executable design architecture from the audit to examine whether the economic framework can be extended under a transparent common health-response scenario.

The World Bank's Healthy Longevity Initiative places this line of analysis within a broader human-capital agenda [9]. Its 2024 research compendium treats prevention and control of non-communicable diseases as protection of both current human capital, through adult survival and productivity, and future human capital, through the health and education of children and their caregivers. It also emphasizes financial protection, poverty and inequality, gendered care responsibilities, and country-owned measurement systems. The compendium summarizes the original ten-country economic model and identifies broader country application, empirical verification of productivity effects, and improved links between intervention costs and health outcomes as priorities for further work. The present study addresses the country-coverage and transparency priorities; it does not estimate the education, intergenerational, distributional or wider welfare pathways described.

Recent WHO investment case documents [10,11] adopt still different, heterogeneous methods: The 2022 case combines heterogeneous intervention-specific economic and social benefit estimates, applies judgements about WHO's contribution to those gains, and reports a benefit–cost ratio for WHO financing. The 2024 case converts projected lives saved into a monetary value using a globally adjusted value of statistical life, before applying achievement and attribution factors. That is principally a welfare valuation of mortality-risk reduction, not an estimate of productivity, GDP, government revenue, or financial return to a health budget. None of the three WHO investment cases adopt a consistent table of accounts.

We propose that health improvements can affect measured economic production by retaining survivors, reducing disability among workers and releasing time spent on care. In the EPIC framework, these changes increase effective labour, while a specified share of additional health expenditure displaces investment and slows physical-capital accumulation [4,5,7]. The estimated GDP effect is the balance between these effects. EPIC depends on an augmented Solow production structure, assumed output elasticities, country saving and depreciation rates, and rules translating mortality, disability, age, labour-force participation and caregiver time into effective labour supply [12,13]. The companion audit addresses the limits of the archived EPIC implementation [8]; the extension reported here corrects identified errors and defects in the 2019 implementation, but holds the EPIC conceptual model and broad structure fixed while significantly broadening country coverage.

Stenberg and colleagues at the WHO modelled resource needs and health outcomes for 67 low- and middle-income countries over 2016–2030 using the OneHealth Tool [6,14]. The published material provides pooled health and spending totals and selected country-level descriptive information, but not a complete set of paired country-specific spending and health responses. It cannot therefore identify a country-level spending elasticity

through a cross-country regression. A pooled average response can instead be imposed as a scenario parameter if its interpretation and transport assumptions are explicit.

The final specification uses a linear spending–health relationship, calibrates mortality effects to programme-specific costs, and treats shared health-system costs separately. Direct disability benefits are anchored to the effect modelled in the audited ten-country reconstruction. Health effects are allocated on accrual proportionally within country burden ceilings. The same pooled health-response coefficients and burden constraints apply to the original ten countries and the country extensions. Spending paths and some macroeconomic initialization conventions remain specific to the original ten-country implementation and are reported explicitly. The approach can be applied with internationally available inputs to a majority of countries in the world.

The objectives were to apply the common response to the countries covered by the published 67-country analysis, extend the scenarios to additional low-income, lower-middle-income and data-ready upper-middle-income economies, report burden saturation and missing-data failures, and make the calculations auditable. The two country groups are described below as the **published-study country group (64 countries)** and the **additional-country group (47 countries)**.

2 Methods

2.1 Design and country coverage

Deterministic paired scenarios were constructed with identical baseline macroeconomic inputs: a baseline arm and an arm receiving additional health spending. The reporting window was 2019–2023, expressed in constant 2014 US dollars without discounting.

The archived ten-country reconstruction covered India, China, Nigeria, Pakistan, Indonesia, the Democratic Republic of the Congo, Bangladesh, Ethiopia, Angola and Brazil. Simulations were completed for 54 further countries in the published-study country group, yielding 64 country results from its original roster of 67. Afghanistan, Eritrea and South Sudan (3 countries) were excluded because compatible capital inputs could not be established; some also had additional macroeconomic gaps.

For the **additional-country group**, the World Bank fiscal year 2027 classification identified 27 low-income or lower-middle-income economies not included in the published 67-country analysis [15]. Simulations were completed for 26. The Democratic People’s Republic of Korea was excluded because the required spending and investment baseline was unavailable. A public-data feasibility screen also identified 21 upper-middle-income economies outside the published-study country group with the macroeconomic, expenditure, mortality and burden inputs required by the model. They are Albania, Argentina, Armenia, Belarus, Belize, Bosnia and Herzegovina, Botswana, El Salvador, Equatorial Guinea, Fiji, Gabon, Georgia, Guatemala, Maldives, Mauritius, Moldova, Mongolia, Montenegro, North Macedonia, Paraguay and Serbia. The current income classification defines the extension group but does not change the 2019 economic anchor.

2.2 Data and provenance

The published article and appendix supplied the pooled mortality and programme-cost calibration [14]. An archived analytical bundle supplied burden arrays, intervention contrasts, costs and macroeconomic inputs for the original ten countries. The companion audit documents the source defects, corrections and limits of that reconstruction [8]. Its production structure follows the WHO EPIC framework, which links health to effective labour and physical capital [4,5]. Population, mortality and disability arrays were derived from Global Burden of Disease sources [16]. The run kit records the transformations used for this extension; the audit paper [8] is the source for claims about the 2019 implementation.

The country extensions used World Development Indicators for population, age–sex shares, labour participation, GDP, health expenditure and investment [15]; WHO age–sex mortality rates for 2019 [18]; and Penn World Table 9.0 for capital, depreciation, labour share and human capital [19,20]. Where World Development Indicators fixed-investment series were missing, Penn World Table 11.0 national-accounts ratios were used [21]. These fallbacks preserve fixed investment rather than substituting gross capital formation including inventories. Country-specific substitutions are listed in the JSON audit trail. For Kiribati, a World Development Indicators national estimate of labour participation was used because the modelled series was unavailable.

Two levels of reproducibility are distinguished. The frozen data, scripts and expected outputs in the run kit support an offline numerical rerun. A separate downloader permits fresh retrieval of public sources without overwriting frozen inputs. The five original spreadsheet export links require authentication. A read-only extraction utility is included, and access may be requested from the author; complete source-to-model reconstruction will also require verification of the workbook cell mappings. Numerical results remain reproducible from the distributed frozen extracts.

2.3 Policy dose and estimand

For every extension, additional spending was 10% of the modelled baseline national health-spending flow in each of five years. Over 5 years, this amounts to an increment of 50% spending, which is comparable to the spending required to reach Universal Health Coverage studied in Stenberg et al. [14]. Let baseline GDP be Y_{ct}^B , the 2019 health-spending share be h_c , the proportional increment be $x=0.10$, and the share of the increment assigned to modelled programmes be $f_c=1$:

$$\Delta C_{ct} = x h_c Y_{ct}^B, S_c = \sum_{t=2019}^{2023} \Delta C_{ct}.$$

The 10% increment is sustained rather than compounded. Incremental spending in the ten-country reconstruction follows the archived study paths; its five-year total is \$220.577 billion. The combined results therefore do not represent a uniform proportional dose in every country. The primary extension assumes that the entire increment is assigned to the modelled programme envelope. This is a scenario condition, not an observation that all baseline national health expenditure, or all real-world incremental spending, belongs to those programmes. An earlier two-category upper-middle-income exercise assigning 60% of the increment to noncommunicable and respiratory disease is retained in the run kit as a sensitivity analysis, not as the primary extension.

The principal estimand is the difference between the five-year sums of scenario GDP. GDP per capita is reported separately at year five. Neither measure is a fiscal return or a benefit–cost ratio.

2.4 Mortality and disability calibration

Seven postbirth mortality rows from the ambitious scenario in Table 7 of the published resource-needs analysis were summed, excluding stillbirths, to obtain 85.43 million deaths averted [14]. The programme-cost denominator is the reported \$963 billion total in appendix Table S21 for 2016–2030. The rounded component costs sum to \$964 billion; the reported total is retained and the discrepancy is recorded.

$$a_D = \frac{85.43 \times 10^6}{963 \times 10^9} \times 10^6 = 88.712357 \text{ deaths per million dollars.}$$

This coefficient assigns the reported health outcomes to programme costs while omitting shared enabling costs. It is a conditional programme-cost scenario parameter, not a full-system cost-effectiveness estimate. The source programmes also do not map exactly onto the six broad disease categories available to the economic model.

The direct disability coefficient is calibrated to the audited ten-country reconstruction of the WHO EPIC production framework [5,8]. That reconstruction yields 64,520,443.979 direct YLDs averted against \$220,577,241,126.046 additional spending over 2019–2023:

$$a_U = \frac{64,520,443.979}{220,577,241,126.046} \times 10^6 = 292.507258 \text{ YLDs per million dollars.}$$

This disability anchor is model-based. In the ten-country reconstruction, cause-specific baseline YLDs are scaled by the corresponding mortality-reduction fraction. A decomposition of published healthy-life-year gains into survival and disability components would require additional timing and survivor-disability assumptions and is therefore not used for the direct-YLD coefficient. The final simulation deducts age-specific residual disability among additional survivors rather than imposing a uniform disability fraction on every survivor.

The unconstrained five-year targets are:

$$T_c^D = a_D \frac{f_c S_c}{10^6}, T_c^U = a_U \frac{f_c S_c}{10^6}.$$

This imposes a linear benefit–increment relationship below saturation.

2.5 Eligible burden and allocation

Mortality eligibility includes noncommunicable disease, HIV and tuberculosis at all ages, and malaria, diarrhoeal disease and respiratory infection below age five. The disability envelope includes the full six-category baseline YLD burden at all ages. This deliberately broad disability envelope differs from the original intervention-specific age restrictions. It is not a claim that childhood interventions directly treat adult disease.

For outcome z equal to deaths or YLDs, let b_{ci}^z be eligible baseline burden in a country’s age–sex–disease–year cell, and let B_c^z be its sum across the reporting window. The common reduction fraction, allocated gain and shortfall are:

$$B_c^z = \sum_i b_{ci}^z, r_c^z = \min\left(\frac{T_c^z}{B_c^z}, 1\right).$$

$$g_{ci}^z = r_c^z b_{ci}^z, G_c^z = \min(T_c^z, B_c^z), F_c^z = T_c^z - G_c^z.$$

The implementation treats zero capacity explicitly. No benefit exceeds a cell’s eligible burden. Mortality and disability are allocated independently, with no imposed cell-level mortality–disability proportionality. The allocation does not maximize GDP or favour working ages. Annual gains follow annual eligible burden, so they need not equal a constant benefit per dollar within each year. Saturation caps benefits but retains full spending. No new health gains or survivor accumulation are assigned in 2018, although the macroeconomic initialization of the ten-country reconstruction is retained.

2.6 Demography and transported profiles

For extensions, 2019 population is expanded from sex-specific five-year age shares, uniformly within closed age groups. The 80-plus group is distributed with an exponential tail of scale six years through age 100 and rescaled

to the country total. Baseline age structure is held fixed while total population grows at the 2014–2019 log-linear trend. This is a simplifying exposure model, not a full demographic forecast.

WHO annual death rates are converted to probabilities:

$$q_{ca} = 1 - \exp(-m_{ca}).$$

The rate for people aged 85 years and older is repeated through age 100. Death probabilities in the ten-country reconstruction instead derive from archived all-cause death counts divided by common exposure. Detailed cause shares and disability rates for country extensions are unweighted averages of selected donor countries from the reconstruction. Donor choices reflect regional and epidemiological judgement rather than statistically estimated similarity. Labour-age profiles are shifted on the logit scale to match country-specific male and female participation. Participation is used as an effective labour-supply input and does not guarantee employment.

2.7 Survivors and effective labour

Additional survivors age by one year between periods. The open age group conserves survivors. If V_{cat}^{start} is the aged survivor stock, q_{cat}^A the intervention death probability, and d_{cat} direct deaths averted, then:

$$V_{cat}^{end} = V_{cat}^{start} (1 - q_{cat}^A) + d_{cat}.$$

$$P_{cat}^V = \frac{V_{cat}^{start} + V_{cat}^{end}}{2}.$$

Midyear survivor person-years approximate exposure within the year. Additional survivors face residual mortality; direct deaths averted therefore differ from net survivors retained. With direct YLD gain u_{cat} and remaining disability rate $\dot{u}_{cat}^A$, the net disability-equivalent gain available for labour calculations is:

$$\Delta U_{cat}^{net} = u_{cat} - P_{cat}^V \dot{u}_{cat}^A.$$

For ages 15–69, participation is multiplied by an experience weight:

$$w_{ca} = l_{ca} \rho_a, \rho_a = 0.8 + 0.02(a - 15) - 0.0002(a - 15)^2.$$

Working-age mortality gains add survivor person-years weighted by w . Net disability gains are converted one for one into equivalent time, then weighted by participation and experience. Caregiver time released is one year per under-five YLD averted and one half year per YLD averted at ages 5–14, weighted by sex-pooled participation and experience at ages 30–44. These are assumptions rather than estimates of observed work absence. Calculations for the ten-country reconstruction use corresponding broad age-group averages. Baseline labour is not separately reduced by baseline YLDs in the primary specification.

$$L_{ct}^A = L_{ct}^B + \sum_a w_{ca} P_{cat}^V + \sum_a w_{ca} \Delta U_{cat}^{net} + L_{ct}^{care}.$$

The sums in the worker terms are restricted to working ages and include both sexes. Remaining disability among survivors can reduce morbidity or caregiver gains. Benefits to children are not valued as future lifetime earnings beyond the five-year window.

2.8 Production and capital

Both arms use the same augmented Solow structure with a Cobb–Douglas production function and normalization [10,11]:

$$Y_{ct}^j = \gamma_c A_{ct} (K_{ct}^j)^{\alpha_c} (H_c L_{ct}^j)^{1-\alpha_c}, j \in \{B, A\}.$$

The scale factor is calibrated to baseline output only. Human capital is fixed. A missing level is normalized to one and absorbed into the common scale; no health-induced schooling effect is added. Where a usable PWT labour share is missing, the capital elasticity is set to 0.4 and tested at 0.3 and 0.5.

Country-specific initial capital is valued at 2014 market exchange rates, using asset stocks and an independent PWT price-level check. Asset consumption divided by asset stock gives depreciation. Extensions bridge 2014 capital with fixed investment flows dated 2015–2018 and use the resulting stock as the 2019 starting value. Real GDP is anchored to 2014 current-dollar GDP using subsequent real-volume ratios. The residual productivity trend subtracts capital-bridge and population growth contributions from the 2014–2019 GDP trend; it includes omitted labour and human-capital trends.

Let $\widetilde{K}_{ct}^A$ be capital before the current financing deduction, i_c the fixed-investment ratio and $\phi = 0.10$ the displacement fraction. The primary analysis retains the 10% investment-displacement assumption used in the earlier work [4,7]:

$$K_{ct}^A = \widetilde{K}_{ct}^A - \phi \Delta C_{ct}.$$

$$\widetilde{K}_{c,t+1}^j = (1 - \delta_c) K_{ct}^j + i_c Y_{ct}^j.$$

For the baseline, pre- and post-deduction stocks coincide. The ten-country reconstruction retains a saving-rate closure: previous-year saving augments depreciated capital, and the current incremental cost deduction occurs before current output. Its baseline is initialized in 2018, whereas the additional country group uses a 2019 anchor.

Six additional economies without capital inputs–Kiribati, Papua New Guinea, Solomon Islands, Somalia, Timor-Leste and Vanuatu–use a pooled estimate from the 42 completed low-income and lower-middle-income countries in the published-study group. The unweighted median 2014 capital-to-GDP ratio is 2.1908 and median depreciation is 5.0586%. The ratio is applied to each country’s 2014 GDP from the World Development Indicators and then bridged using its investment. The first and third quartiles, 1.7843 and 2.6102, define the capital-ratio sensitivity cases. These six projections are reported separately because they require stronger economic assumptions.

2.9 Aggregation and sensitivity

Five-year absolute and relative GDP gains are:

$$\Delta Y_c = \sum_t (Y_{ct}^A - Y_{ct}^B), g_c = 100 \frac{\Delta Y_c}{\sum_t Y_{ct}^B}.$$

For a country group, combined year-five GDP per capita is computed from summed output and population in each arm:

$$g^{pc} = 100 \left[\frac{\sum_c Y_{c,2023}^A / \sum_c N_{c,2023}^A}{\sum_c Y_{c,2023}^B / \sum_c N_{c,2023}^B} - 1 \right].$$

Scenario population adds midyear survivor person-years to baseline population. Group GDP-per-capita changes are not averages of country percentages but calculated directly.

Reported sensitivities vary the capital elasticity default in 15 countries in the published-study extension and 11 countries in the additional-country group. They do not constitute a comprehensive sensitivity analysis of all assumptions. Changes in the capital elasticity preserve the recorded productivity trend while renormalizing initial GDP and recomputing spending and health targets. Capital-ratio sensitivity analysis for the additional-country group rebuild the capital bridge and residual productivity trend while retaining observed GDP trends. It does not capture uncertainty about transported health profiles, disability-to-work conversion and shared-system capacity.

2.10 Verification and audit trail

The kit recalculates both response coefficients, rebuilds extension inputs, reruns all final country models from frozen inputs and selected sensitivity tests, reconciles annual and cumulative GDP, and compares results against frozen expected values. Checks include positive capital and labour; bounded risks and benefits; survivor-stock identities; no spending reduction at saturation; zero-dose and cost-only controls; and complete accounting of the 111 economies. Numerical comparison uses relative tolerance 10^{-10} and absolute tolerance 10^{-5} in stored units. All 111 completed results matched.

3 Results

3.1 Coverage and aggregate output

Of the 67 countries in the published resource-needs analysis, 64 were able to be completed. Of 27 additional low-income and lower-middle-income economies, 26 were able to be completed. All 21 data-ready upper-middle-income economies were able to be completed. In total four economies were excluded during input construction. Country-specific tables are provided in Appendices A–C; full-precision annual outputs are included in the run kit.

Table 1 Aggregate economic results

Country group	n	Extra spending	Extra GDP	GDP gain %	Year 5 GDP per capita %
Published resource-needs analysis	64	460.065	630.920	0.3768	-0.0805
Additional LIC and LMIC economies	26	11.430	9.879	0.4696	0.1785
Additional UMIC economies	21	42.926	76.218	1.4990	-0.2162
All additional economies	47	54.356	86.097	1.1977	0.4057
Combined descriptive total	111	514.421	717.017	0.4106	-0.0667

All monetary columns in Table 1 are billions of constant 2014 US dollars. The 111-country total is a descriptive sum across heterogeneous policy doses and model conventions rather than a common-dose estimate. The published-study and harmonised additional-country results are therefore the primary comparisons.

All 64 countries in the published-study group and all 47 additional economies had positive cumulative GDP gains. Year-five GDP per capita increased in 27 published-study countries, 18 additional low-income and lower-middle-income economies and 5 of the 21 upper-middle-income economies. China contributed \$128.940 billion of additional GDP, followed by Mexico (\$83.406 billion) and Argentina (\$48.054 billion). Absolute differences partly reflect economic size and should not be interpreted as differences in marginal effectiveness.

The ten countries included in the 2019 analysis generated \$228.296 billion in additional GDP under the present burden-constrained extension specification, against \$220.577 billion in additional spending. This result belongs to the common extension scenario and is not a revised estimate of the historical analysis. The companion audit reports the reconstruction of the 2019 estimates and the consequences of its source and implementation problems [8].

3.2 Mortality and disability outcomes

The published-study group achieved 38.759 million direct deaths averted and 134.572 million direct YLDs averted. The 47-country harmonised additional extension achieved 3.748 million direct deaths averted and 15.900 million direct YLDs averted. Across the 111 completed economies, the corresponding totals were 42.507 million and 150.472 million.

Table 2 Mortality targets and shortfalls at saturation

Country	Target deaths	Achieved deaths averted	Unmet target
Mexico	3,536,706	2,619,135	917,571
Colombia	1,556,910	950,043	606,867
Ecuador	388,762	310,666	78,096
Malaysia	797,945	775,013	22,932
Turkey	2,347,121	1,933,955	413,166
Iraq	587,973	572,002	15,971
Lebanon	165,108	107,292	57,816
West Bank and Gaza	71,125	56,218	14,907
Argentina	2,297,086	1,338,529	958,557
Maldives	18,613	10,392	8,221
Mauritius	43,757	41,683	2,074
Paraguay	155,507	122,733	32,773

Twelve economies reached the mortality ceiling. The combined unmet mortality target was 3.129 million deaths, with full spending retained. None reached the YLD ceiling. Saturation is a completed capped projection, not successful delivery of the uncapped target. Eliminating all eligible baseline deaths is a mathematical ceiling and should not be read as operational feasibility.

3.3 Additional countries with imputed capital

The 20 additional economies with country-specific capital inputs generated \$9.384 billion in additional GDP against \$10.844 billion in spending. The six with imputed capital generated \$0.495 billion against \$0.587 billion. Their totals are included in the additional-country group result and are separately identified in Appendix B. This distinction concerns capital inputs; all additional country extensions depend on transported health profiles.

Senegal generated \$0.309 billion in additional GDP against \$0.692 billion in spending, with year-five GDP per capita changing by -0.0392% . Zambia generated \$0.869 billion against \$1.129 billion, with GDP per capita changing by $+0.2391\%$.

3.4 Sensitivity results

Varying the capital elasticity between 0.3 and 0.5 in 15 published-study countries changed the GDP gain for the 64-country published-study group to \$626.600–\$634.813 billion, compared with \$630.920 billion in the central scenario. The same variation in 11 additional countries changed the group result to between \$9.431 and \$10.313 billion. Capital-ratio quartile scenarios for the six countries with imputed capital produced group gains of between \$9.874 and \$9.882 billion. Some country-level GDP-per-capita signs changed when the capital elasticity varied.

Large inherited capital/GDP ratios in Tajikistan (15.61) and Venezuela (18.86), and Venezuela's sharply declining historical GDP trend, are retained and flagged. They indicate sensitivity to source vintage and macroeconomic extrapolation. No cap was introduced merely to make these results appear more plausible.

The earlier upper-middle-income sensitivity restricted the envelope to noncommunicable and respiratory disease and set $f = 0.60$. It generated \$76.218 billion in additional GDP against \$42.926 billion in spending for the same 21 economies. It is not pooled with the primary result because its policy dose and disease envelope differ. The primary six-category, $f = 1$ scenario is reported above so that the upper-middle-income extension uses the same health-response and programme-envelope assumptions as the 26 additional low-income and lower-middle-income economies.

4 Conclusions

Under the stated programme-cost, health-response and macroeconomic assumptions, additional health spending produces positive five-year production gains in all 111 completed country scenarios. Aggregate GDP gains exceed additional spending in the published-study group and in the 47-country harmonised additional extension. Across all completed scenarios, the descriptive GDP gain exceeds spending by \$202.596 billion. GDP per capita need not rise when aggregate GDP rises because additional survivors also increase population.

The policy value of these estimates lies in showing the production channel that may accompany health gains and in making the underlying assumptions testable. In full investment cases, production effects should be considered alongside health outcomes, distribution, financial protection, implementation capacity, full health-system costs and fiscal space [1–5].

5 Discussion

5.1 Relevance to WHO health investment policy

WHO uses economic analysis to support universal health coverage, health investment cases and assessments of the contribution of health to economic performance [1,5,10,11]. The present scenarios revisit and extend the production analysis that informed the 2018 WHO Investment Case [3,4]. They translate specified mortality and disability gains into short-horizon changes in effective labour, capital and GDP, thereby making the mechanism and its assumptions available for audit across a wider set of countries. The scenarios can help identify the scale and timing of potential production effects and show when mortality ceilings or financing assumptions materially constrain results.

Recent WHO investment cases [10,11] use the term “return on investment” for materially different quantities. The 2022 and 2024 WHO investment cases attempt to answer a different question: what is the value attributable to investment in WHO as an institution? The 2022 case combines heterogeneous intervention-specific economic and social benefit estimates, applies judgements about WHO’s contribution to those gains, and reports a benefit–cost ratio for WHO financing. The 2024 case converts projected lives saved into a monetary value using a globally adjusted value of statistical life, before applying achievement and attribution factors.

These approaches may all support the broad proposition that investments which improve health can create substantial social value. However, their numerical results are not directly comparable, and the common label “ROI” can obscure crucial distinctions: between welfare value and national output; between gross potential productivity and net GDP; between benefits to societies and benefits accruing to public budgets; and between the outcomes of collective action and the share attributed to WHO. Future investment cases would be clearer and more contestable if they reported these components separately, named the economic concept being valued, showed the relevant counterfactual and assumptions, and avoided presenting a single monetised return as though it had one unambiguous meaning.

The policy framework of The World Bank’s Healthy Longevity Initiative spans near-term changes in adult survival and productivity, longer-term effects on education and intergenerational human capital, household financial protection, inequality, gendered caregiving and functioning at older ages [9]. The present model quantifies only a subset of the near-term production pathways. It excludes educational accumulation, most lifetime gains to children, distributional consequences and the intrinsic value of health. The estimates should therefore be used as a transparent production module within a wider investment case, not as a summary measure of the benefits of healthy longevity.

WHO’s universal health coverage framework also emphasizes access to essential services and financial protection [1], while the Council on the Economics of Health for All places health within a broader account of public value and distribution [2]. A positive GDP effect is neither necessary nor sufficient to justify a health programme. Decisions still require evidence on population health, equity, financial risk protection, delivery capacity, fiscal sustainability and opportunity cost.

The ratio of additional GDP to additional spending is not a social return on investment. Longer lives, better health, financial risk protection and distributional effects have value that is not captured by measured output. A comprehensive economic evaluation would specify these benefits and costs in an explicit table of accounts and avoid both double counting and the omission of important non-market outcomes [22]. Such an evaluation would generally record more benefits than the present GDP-only exercise, but whether its benefit–cost ratio exceeds one should be demonstrated through explicit valuation rather than inferred merely from the production results.

5.2 Interpretation of the pooled response

A linear response is parsimonious where paired country-specific data are absent, but parsimony does not confer validity. The pooled coefficient averages over interventions, countries and a 15-year source horizon. Applying it uniformly to five-year country envelopes assumes transportability across baseline burden, delivery capacity and timing. Saturation prevents numerical impossibilities but does not validate the response below the ceiling.

The programme-only denominator raises the mortality response relative to an all-cost denominator. This is not a newly discovered technical efficiency; it is an accounting choice that credits health outcomes while excluding shared health system investment. The assumed availability of facilities, workforce, supply chains and management capacity is therefore central. A later full-system analysis should restore system costs and model their contribution, rather than simply interpret current ratios as national spending returns.

5.3 Disability and the output mechanism

Direct YLD effects are anchored to a model whose morbidity reductions follow mortality reductions within cause-age cells. This merely supplies a coherent internal comparator. Moreover, one YLD is not necessarily one work-year lost: disability weights measure health loss, while work consequences depend on disease, occupation, accommodation and labour-market conditions. The assumed conversion into worker and caregiver time may overstate or understate production benefits.

The model also omits education gains, most lifetime benefits to children, fertility changes, household risk protection and non-market wellbeing. These omissions can reduce measured short-horizon benefits, while other assumptions can increase them.

5.4 Transfers and financing

The additional-GDP-to-spending ratio is 1.371 in the published-study group and 1.584 in the 47-country harmonised additional extension; the descriptive ratio across all 111 countries is 1.394. Output gains are not government revenue, and only a fraction might be taxed or transferred. The all-country aggregate is compatible with a transfer-payment accounting regime in which gains in some economies offset costs in others; it does not establish that any individual country, subsample, or health budget pays for itself. The analysis omits collection, distribution, timing, cross-border arrangements and shared-system costs. International transfers could redistribute financing burdens, but these scenarios do not establish their feasibility.

5.5 Transportability and model comparability

Detailed health profiles are selected by judgement rather than estimated through formal matching. Results for the low-income/lower-middle-income and data-ready upper-middle-income extensions are therefore identified separately. In the upper-middle-income extension, the detailed six-category age-sex profile is a pooled ten-country profile rather than a country-specific match. Independent health-response data, country YLD profiles and validation would be required to establish transportability.

The original ten-country model and later country extensions retain different macroeconomic closure and initialization conventions. Their pooled totals combine different policy doses, input vintages and baseline dynamics. The common spending-to-health coefficients and burden constraints improve comparability, but they do not remove these remaining differences. Current income classifications can also differ from those in effect when the published resource-needs analysis selected its country group. A future harmonized analysis should use common source vintages, population projections, policy doses, capital timing and economic closure before country rankings are interpreted as structural differences. The companion audit provides a detailed assessment of the original implementation [8].

5.6 Reproducibility and remaining evidence needs

The run kit supports a numerical rerun from the enclosed frozen inputs without a network connection. Public downloads are separately addressable and logged with hashes. The original spreadsheets require author-approved access. A read-only extraction utility is provided, but complete raw-data reconstruction also requires verification of the source-to-model mappings. These conditions distinguish numerical reproducibility from unrestricted reconstruction of every upstream input.

Priority evidence needs are country-specific marginal health responses, a programme/shared-system cost bridge, direct disability effects and labour consequences, and better demographic and economic projections. Sensitivity analyses should examine these structural uncertainties jointly. The present selected parameter variations do not provide statistical uncertainty intervals.

Authors contributions

Jeremy A. Lauer. Conceptualization; formulation of the policy questions; methodological direction and supervision; selection and revision of the spending, mortality, disability, allocation and country-extension assumptions; provision of source materials; interpretation of results; and critical review of the analysis. Final manuscript revision, approval and accountability rest with the author.

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OpenAI ChatGPT, accessed through the Codex environment, assisted with source retrieval, data curation, programming, calculation, reproducibility packaging, internal consistency checks, drafting and document preparation under the author's direction. The author supplied the research direction and made the substantive scenario decisions.

Declarations

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Data and code availability. The accompanying run kit contains frozen analytical inputs, source manifests, public retrieval scripts, transformations, assumptions, expected outputs and executed audit logs. Access to five private source workbooks may be requested from Jeremy A. Lauer, Unexia Association, at jlauer@unexia.org. The kit includes a read-only authenticated extraction utility. Original sources retain their respective rights; the run kit does not grant new rights to third-party data.

Ethics and participant data. The analysis uses aggregate country-level and age–sex data and does not process participant-level records.

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Appendix A Countries in the published resource-needs analysis

All money is billions of constant 2014 US dollars. GDP gains and spending are five-year totals. GDP per capita is the year-five percentage change. An asterisk marks mortality saturation; full spending remains charged. Afghanistan, Eritrea and South Sudan are excluded and are not represented by zeros.

Country	Spending \$bn	GDP gain \$bn	GDP gain %	Year 5 GDP per capita %
Algeria	7.359	13.049	0.9607	-0.0432
Angola	3.673	4.023	0.4814	-0.2818
Azerbaijan	1.556	1.093	0.2937	-0.7804
Bangladesh	7.635	4.831	0.3460	0.0923
Benin	0.281	0.153	0.1637	0.0451
Brazil	6.598	18.818	0.1563	-0.0339
Burkina Faso	0.550	0.160	0.1555	-0.0000
Burundi	0.154	0.008	0.0451	-0.0537
Cambodia	0.931	0.696	0.3777	0.0745
Cameroon	0.883	0.524	0.2166	0.0283
Central African Republic	0.096	0.001	0.0047	-0.1506
Chad	0.338	0.147	0.1473	0.0384
China	69.212	128.940	0.1682	-0.1533
Colombia*	17.550	37.939	1.6935	0.3215
Comoros	0.036	0.019	0.2800	0.0097
Côte d'Ivoire	1.205	1.006	0.2665	0.0379
DRC	6.667	1.580	0.5607	0.0910
Dominican Republic	2.205	6.964	1.3795	0.1578
Ecuador*	4.382	5.499	0.9798	-0.3343
Egypt	9.912	7.799	0.3619	-0.1914
Ethiopia	10.163	0.532	0.1275	-0.6093
Gambia	0.027	0.007	0.0837	0.0263
Ghana	1.245	1.110	0.2901	0.0840
Guinea	0.267	0.044	0.0678	-0.0685
Guinea-Bissau	0.058	0.018	0.2187	0.0627
Haiti	0.322	0.164	0.1989	0.0387
India	55.889	19.790	0.1258	-0.1363

Country	Spending \$bn	GDP gain \$bn	GDP gain %	Year 5 GDP per capita %
Indonesia	21.738	27.514	0.4044	-0.0721
Iran	15.302	9.220	0.3757	-0.8429
Iraq*	6.628	8.911	0.5657	-0.4079
Kazakhstan	3.929	11.571	0.8456	-0.4125
Kenya	2.046	0.937	0.2001	-0.0289
Liberia	0.132	0.024	0.1507	-0.0144
Madagascar	0.250	0.040	0.0493	-0.0043
Malawi	0.366	0.064	0.1114	-0.0061
Malaysia*	8.995	32.726	1.3971	-0.1885
Mali	0.471	0.198	0.1614	0.0376
Mexico*	39.867	83.406	1.1091	-0.4439
Morocco	3.707	3.490	0.4726	-0.1644
Mozambique	0.853	0.141	0.1303	-0.0341
Myanmar	1.861	1.044	0.2139	0.0120
Nepal	0.742	0.266	0.1593	-0.0001
Niger	0.453	0.072	0.0905	-0.0314
Nigeria	17.894	10.856	0.2637	-0.2839
Pakistan	21.108	11.411	0.6721	0.0431
Peru	6.363	6.501	0.5236	-0.7994
Philippines	9.776	8.680	0.3699	-0.1538
Romania	7.988	18.884	1.3472	-1.5611
Rwanda	0.324	0.156	0.2370	0.1082
Sierra Leone	0.257	0.077	0.1719	-0.0298
South Africa	16.722	34.611	1.7068	0.1226
Sri Lanka	1.933	2.874	0.5502	0.0242
Sudan	1.174	0.415	0.1625	0.0138
Tanzania	1.563	0.555	0.1430	0.0003
Thailand	9.796	11.673	0.4515	-0.4620
Togo	0.259	0.161	0.3673	0.2060
Tunisia	1.698	1.791	0.6353	-0.2869
Turkey*	26.458	69.344	1.1426	-0.5990

Country	Spending \$bn	GDP gain \$bn	GDP gain %	Year 5 GDP per capita %
Uganda	0.873	0.361	0.1570	0.0560
Ukraine	4.898	2.910	0.4215	-0.3089
Uzbekistan	3.518	4.711	0.6474	0.0382
Viet Nam	9.247	9.946	0.5350	-0.0190
Yemen	1.342	0.301	0.2462	0.0364
Zimbabwe	0.338	0.163	0.1555	0.0334

Appendix B Additional-country projections

An asterisk marks mortality saturation. A dagger marks initial capital and depreciation imputed from the 42-country low-income and lower-middle-income pool in the published-study group. The Democratic People's Republic of Korea is excluded for missing inputs; Costa Rica is deferred. These are additional-country scenario projections, not externally validated forecasts.

Country	Spending \$bn	GDP gain \$bn	GDP gain %	Year 5 GDP per capita %
Senegal	0.692	0.309	0.2008	-0.0392
Zambia	1.129	0.869	0.5198	0.2391
Bolivia	1.437	1.143	0.5478	-0.2193
Bhutan	0.049	0.054	0.3711	-0.0199
Congo, Rep.	0.156	0.146	0.2195	0.0867
Djibouti	0.040	0.044	0.2646	0.0676
Honduras	0.944	0.794	0.6179	0.0747
Kyrgyz Republic	0.212	0.092	0.1836	0.0022
Kiribati†	0.014	0.011	0.8143	0.1832
Lao PDR	0.274	0.217	0.2059	-0.0063
Lebanon*	1.861	2.540	1.1852	-0.4582
Lesotho	0.265	0.119	0.9823	0.4164
Mauritania	0.134	0.074	0.1706	0.0060
Namibia	0.554	0.811	1.2974	0.2049
Nicaragua	0.546	0.296	0.4609	-0.0705
Papua New Guinea†	0.354	0.383	0.2516	0.0489
West Bank and Gaza*	0.802	0.935	1.0717	0.2644
Solomon Islands†	0.037	0.031	0.3666	0.1309
Somalia†	0.116	0.024	0.0492	0.0065
Sao Tome and Principe	0.010	0.008	0.4021	0.1248
Eswatini	0.221	0.437	1.6595	0.7574
Syrian Arab Republic	0.376	0.112	0.1186	0.0101
Tajikistan	0.513	0.157	0.2132	-0.1247
Timor-Leste†	0.047	0.021	0.2215	0.0145
Venezuela	0.627	0.226	0.0789	-0.0653
Vanuatu†	0.019	0.025	0.4739	0.1526

Appendix C Additional upper middle income economies

Country	Spending \$bn	GDP gain \$bn	GDP gain %	Year 5 GDP per capita %
Albania	0.555	0.772	0.9435	-0.4233
Argentina*	25.894	48.054	1.8779	-0.4084
Armenia	0.911	1.267	1.5823	-0.5006
Belarus	2.339	4.430	1.1104	-0.4902
Belize	0.055	0.109	0.9580	0.1884
Bosnia and Herzegovina	1.054	1.743	1.4757	-0.7511
Botswana	0.585	0.867	0.9073	-0.6465
El Salvador	1.182	1.591	1.1856	0.0218
Equatorial Guinea	0.210	0.558	0.8722	0.2565
Fiji	0.126	0.222	0.7534	-0.0705
Gabon	0.289	0.438	0.4193	-0.3212
Georgia	0.908	1.316	1.0597	-0.4923
Guatemala	2.276	2.275	0.6172	-0.1949
Maldives*	0.210	0.557	1.9927	0.6630
Mauritius*	0.493	1.277	1.4740	-1.0539
Moldova	0.385	0.475	0.8026	-0.1780
Mongolia	0.391	0.560	0.6437	-0.0214
Montenegro	0.246	0.533	1.8020	-0.8514
North Macedonia	0.485	0.686	0.9990	-0.7061
Paraguay*	1.753	3.665	1.4971	0.2200
Serbia	2.579	4.823	1.5498	-0.9857

Appendix D Run kit and audit map

The principal offline command is `python run_all.py` from the unzipped kit directory, using Python 3.10 or newer. It uses the standard library and does not require Excel, R or an internet connection. The expected output is an audit status of passed, 64 published-study results, 26 additional low-income and lower-middle-income results, and 21 harmonised upper-middle-income results, with four recorded exclusions. The script writes fresh numerical results into outputs and stage logs into audit. It also rebuilds intermediate component outputs; keep an untouched copy when experimenting.

Public retrieval is separate: `python fetch_public.py --ids S015 S026 S117` demonstrates selected World Bank, WHO and PWT sources. Without an ID filter, it attempts every non-restricted manifest entry. Restricted original archive URLs are excluded unless explicitly requested with `--include-restricted`; this flag does not bypass authentication. Download failures are logged and do not overwrite frozen data. Fresh data can differ by vintage, and the kit does not silently replace inputs or promise byte-identical upstream files.

File or directory	Purpose
<code>run_all.py</code>	Offline rerun, coefficient reconstruction, expected-result comparison
<code>fetch_public.py</code>	Download selected public sources into a separate directory
<code>provenance/sources.json</code>	Source URLs and retrieval history
<code>provenance/countries.json</code>	Country-level input, donor and model mapping
<code>provenance/transformations.json</code>	Transformation register and code locations
<code>provenance/assumptions.json</code>	Explicit scenario assumptions
<code>provenance/original_archive_access.json</code>	Failed unauthenticated original-source tests
<code>components</code>	Frozen inputs, raw responses, model scripts and diagnostics
<code>expected</code>	Preserved results used for numerical comparison
<code>outputs</code>	Reproduced coefficients, country results, totals and exclusions
<code>audit/run_validation.json</code>	Execution status and result checks
<code>audit/fetch_validation.json</code>	Public-source retrieval smoke test
<code>SHA256SUMS</code>	File integrity manifest

The source manifest contains exact URLs and prior retrieval records. Country provenance maps each result to its component, input file, donor set, policy dose, macro closure and imputation flags. The transformation register explains the path from inputs to coefficients, burden allocation, cohort accounting and GDP. Machine-readable assumptions distinguish modelling choices from observations. SHA256 checksums cover the distributed files. The independently executed numerical comparison and source access tests are retained as JSON and text logs.