Research Square

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Economic value of declining mortality in under five children in Rwanda, 2000 - 2023. Global Burden of Disease estimates Analysis

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Research Article

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Abstract

Background

Rwanda has achieved one of the fastest declines in under-five mortality worldwide since 2000, yet the economic value of this transition, and the residual economic burden of child ill-health, remain poorly quantified.

Methods

We used Global Burden of Disease (GBD) 2023 estimates (Institute for Health Metrics and Evaluation) for Rwanda to characterise trends in under-five deaths, disability-adjusted life-years (DALYs), and leading causes, 1990–2023. Deaths averted were estimated using the standard demographic convention (change in the under-five mortality rate multiplied by contemporaneous live births, relative to a year-2000 baseline). DALY burden was monetised using Rwanda's own empirically estimated health-system opportunity cost per DALY, with GDP-per-capita-multiple thresholds reported as sensitivity comparators.

Results

Under-five deaths fell from approximately 55,800 in 2000 to 19,100 in 2023, a decline of 65.7%, and under-five DALYs fell by 64.8% over the same period. We estimate approximately 698,000 cumulative deaths were averted, 2001–2023, relative to year-2000 mortality conditions. Neonatal disorders, lower respiratory infections, malaria, congenital birth defects and diarrhoeal disease remained the five leading causes of under-five death in 2023, together accounting for over 70% of deaths, even as the composition shifted markedly toward neonatal causes. At Rwanda's estimated opportunity cost of US$520 per DALY, the current annual under-five burden is valued at approximately US$923 million, and the value of the burden reduction achieved since 2000 is approximately US$1.70 billion per year. Child and maternal malnutrition is the single largest modifiable risk factor, accounting for 41.5% of under-five DALYs and an estimated US$383 million in annual economic burden, which exceeds current government nutrition-targeted financing.

Conclusions

Rwanda's under-five health transition represents a very large, quantifiable economic gain, but a substantial and unevenly distributed burden persists, concentrated in the neonatal period and in malnutrition. Continued, targeted investment, particularly in neonatal care and in nutrition-specific and nutrition-sensitive programming, is economically justified under Rwanda's own estimated health-opportunity-cost threshold.

1. Introduction

Between the 1994 genocide against the Tutsi, which devastated Rwanda's health workforce and infrastructure, and the present day, the country's child-survival record has moved from among the world's

worst to among its most improved. GBD 2023 estimates place Rwanda's under-five mortality rate (U5MR) at 164.0 per 1,000 live births in 2000, a level close to the immediate post-genocide years, during which under-five deaths spiked to an estimated 89,800 in 1994 alone [1]. By 2023, U5MR had fallen to 52.2 per 1,000, a 68.2% relative decline achieved within a generation. This places Rwanda among the fastest-improving countries globally over the period and has been widely attributed to deliberate, sequenced health-system investment: community-based health insurance (Mutuelles de Santé) from 2004, nationwide performance-based financing (PBF) of health facilities from 2006 [2], and a community health worker platform delivering integrated community case management (iCCM) to village level, associated with a 38% reduction in under-five mortality within a year of national rollout [3].

The epidemiological dimensions of this transition are well documented. Far less established, and the focus of this paper, is its economic dimension: how much Rwanda's child-survival gain is actually worth in terms comparable to other calls on the health budget, and how large the economic burden of what remains still is. Existing Rwandan child-mortality literature has concentrated on measuring the decline and its distribution; a companion analysis of Demographic and Health Survey data by the author, for example, documents the narrowing of wealth-based inequality in under-five mortality over 2010–2020 using Fairlie decomposition [4]. To our knowledge, no published analysis has attached an economic value to Rwanda's under-five burden using internationally comparable, cause-specific estimates. This is a consequential gap: economic valuation is what allows child-health gains to be weighed, in the same currency, against competing claims on scarce health and development financing, and what allows the residual burden to be prioritised by cost rather than by epidemiological rank alone.

We address this gap using GBD 2023 estimates for Rwanda, produced by the Institute for Health Metrics and Evaluation (IHME) [1]. GBD data offer three advantages for this purpose: cause-specific mortality and DALY estimates that are internally consistent across the study period and comparable against Rwanda's development peers; an explicit Socio-Demographic Index (SDI) against which observed performance can be benchmarked; and complete annual series back to 1990, capturing both the genocide-era mortality shock and the subsequent transition. We combine these estimates with recently updated, empirically derived health-opportunity-cost thresholds for low- and middle-income countries [5, 6] to produce what is, to our knowledge, the first monetised estimate of the economic burden and economic value of Rwanda's under-five health transition.

Specifically, this paper: (1) documents trends in under-five deaths and DALYs, 1990–2023, and the changing composition of leading causes; (2) estimates the number of under-five deaths averted by Rwanda's mortality decline; (3) monetises the current burden and the value of the decline using Rwanda's own estimated health-opportunity-cost threshold, with sensitivity bounds; (4) quantifies the burden attributable to modifiable risk factors, foremost child and maternal malnutrition, against current targeted public financing; and (5) situates Rwanda's under-five and overall health performance against its socio-demographic development level. We conclude with implications for investment prioritisation as Rwanda pursues the child-survival and nutrition targets of its National Strategy for Transformation (NST2) and Vision 2050.

2. Methods

2.1 Data source and study population

We used publicly documented GBD 2023 estimates, accessed through IHME's GBD 2023 results covering 204 countries and territories, 1990–2023 [1]. The study population was children under five years of age in Rwanda. We extracted: (i) U5MR (5q0, deaths per 1,000 live births), 2000–2023; (ii) all-cause under-five deaths and DALYs, 1990–2023; (iii) cause-specific deaths and DALYs for the leading causes of under-five death in 2000 and 2023; (iv) risk-factor-attributable DALYs among children under five, 2023; (v) Rwanda's SDI, 2000–2023; (vi) life expectancy at birth, 2000–2023, and its decomposition by cause of change; and (vii) actual-versus-SDI-expected life expectancy, 2023. Live births by year, 2000–2023, were extracted to support the deaths-averted calculation below. Point estimates are accompanied by 95% uncertainty intervals (UI) in text where these are materially wide.

2.2 Deaths averted

Following the standard demographic convention used in global child-survival reporting (e.g. the UN Inter-agency Group for Child Mortality Estimation, Countdown to 2030), we estimated deaths averted in year t relative to a 2000 baseline as:

$$\text{Deaths averted}(t) = [\text{U5MR}(2000) - \text{U5MR}(t)] \times \text{LiveBirths}(t) / 1000$$

for t = 2001,…,2023, summed to give cumulative deaths averted over 2001–2023. This convention estimates, for the birth cohort of year t, how many fewer deaths before age five would be expected under year-t mortality conditions than under year-2000 conditions; it is the logic underlying most published "lives saved" estimates and does not require projecting individual life-years. We treat this as a descriptive counterfactual that isolates the change in age-standardised mortality risk itself, rather than as a causal estimate attributable to any specific intervention.

2.3 Economic valuation

We monetised the DALY burden using an estimate of Rwanda's own health-system opportunity cost per DALY: the marginal health benefit the health system is estimated to produce per additional dollar of expenditure, inverted to a cost-per-DALY figure. We used the Rwanda-specific estimate from recently updated cross-country health-opportunity-cost modelling, US$520 per DALY [6], which extends the peer-reviewed methodology of Ochalek, Lomas and Claxton [5]. We favoured this over the more conventional 1–3× GDP-per-capita heuristic historically associated with WHO-CHOICE, because empirical opportunity-cost research finds that GDP-multiple thresholds substantially overstate true health opportunity costs in low-income settings [5]. We nonetheless report GDP-per-capita-multiple valuations (0.5×, 1× and 3× Rwanda's 2024 GDP per capita of approximately US$1,070 [7]) as sensitivity comparators, consistent with standard practice in economic evaluation of presenting results across a plausible range rather than as a single point estimate [8]. Because reference [6] is an updated preprint estimate that has not yet

completed peer review, we treat it as the primary but not the only valuation basis and report the sensitivity range alongside it throughout.

We report: (a) the current (2023) annual monetised under-five DALY burden; (b) the annual monetised value of the reduction in DALY burden between 2000 and 2023; and (c) a cumulative monetised value of DALYs averted over 2001–2023, computed by holding the year-2000 DALY count constant as a simple counterfactual and summing annual differences. This third measure is reported as a conservative cross-check rather than a primary estimate, since it does not formally reweight for the (modest) change in birth-cohort size over the period; live births in Rwanda varied by less than 7% across 2000–2023 in GBD estimates, which limits the scale of this simplification. All monetary values are nominal US dollars, not inflation-adjusted or discounted across years, consistent with their use as same-year illustrative valuations rather than a discounted lifetime cost-benefit analysis.

2.4 Software and reproducibility

Calculations were performed directly on the extracted GBD 2023 series; the deaths-averted and monetisation formulas above, together with the year-by-year estimates in Table 1, allow exact replication. A supplementary Stata script (Appendix A) reproduces the descriptive and sensitivity calculations for readers extending this analysis with Demographic and Health Survey microdata, consistent with the concentration-index and decomposition methods used in related work on wealth-based inequality in Rwandan under-five mortality [4].

2.5 Ethics

This study used only publicly available, de-identified, aggregate secondary estimates (GBD 2023) and publicly reported survey indicators; no primary data were collected and no ethical approval was required.

3. Results

3.1 Trends in under-five mortality and burden, 1990–2023

Rwanda's U5MR was 164.0 per 1,000 live births in 2000. From 2000, U5MR declined in nearly every subsequent year, reaching 52.2 per 1,000 in 2023, a relative decline of 68.2% (Table 1, Fig. 1). All-cause under-five deaths fell from approximately 55,800 in 2000 to 19,100 in 2023, a fall of 36,681 deaths or 65.7%, and under-five DALYs fell from approximately 5.04 million to 1.77 million, a decline of 64.8%, over the same period.

Table 1
Under-five mortality rate, deaths and DALYs, Rwanda, selected years 2000–2023

Year	U5MR (per 1,000 live births)	Under-five deaths	Under-five DALYs
2000	164.0	55,826	5,038,512
2005	106.7	38,268	3,481,678
2010	77.2	27,645	2,534,511
2015	64.6	24,193	2,225,609
2020	55.6	20,697	1,913,298
2023	52.2	19,145	1,774,367

Source: IHME Global Burden of Disease Study 2023, both-sex estimates.

Applying the deaths-averted convention (§ 2.2), we estimate approximately 697,800 cumulative under-five deaths were averted between 2001 and 2023 relative to year-2000 mortality conditions, rising from a negligible number in the early 2000s to an estimated 40,900 deaths averted in 2023 alone. Put differently, the 19,145 under-five deaths recorded in 2023 were approximately one-third of the 60,000 that would have been expected in that year's birth cohort had year-2000 mortality risk persisted.

3.2 Changing composition of leading causes

The cause-of-death composition among Rwandan children under five shifted markedly (Table 2, Fig. 2). In 2000, five communicable and nutritional causes (lower respiratory infections, malaria, diarrhoeal disease, measles and HIV/AIDS) together accounted for 58.3% of under-five deaths. By 2023 the same five causes accounted for 31.9% of a substantially smaller total; measles deaths fell by an estimated 87% and HIV/AIDS deaths by over 90% in count terms. Neonatal disorders, by contrast, rose from 20.6% to 35.2% of under-five deaths, not because neonatal deaths increased (they fell by more than 40% in absolute terms) but because they declined more slowly than post-neonatal infectious causes, a pattern consistent with a health system that has been highly effective against vaccine-preventable and infectious childhood disease and is now confronting the comparatively harder problem of neonatal survival. In 2023 the five leading causes together accounted for 71.8% of under-five deaths and 70.1% of under-five DALYs: neonatal disorders (35.2%), lower respiratory infections (12.5%), malaria (9.1%, wide 95% UI), congenital birth defects (8.8%) and diarrhoeal disease (6.3%).

Table 2
Leading causes of under-five death, Rwanda: 2000 vs 2023

Cause	2000, n	2000, %	2023, n	2023, %
Neonatal disorders	11,485	20.6	6,731	35.2
Lower respiratory infections	8,547	15.3	2,392	12.5
Malaria	8,187	14.7	1,736	9.1
Diarrhoeal diseases	8,138	14.6	1,201	6.3
Measles	4,333	7.8	556	2.9
HIV/AIDS	3,357	6.0	230	1.2
Congenital birth defects	1,439	2.6	1,677	8.8
All other causes	10,340	18.5	4,622	24.1
Total	**55,826**	**100.0**	**19,145**	**100.0**

Source: IHME Global Burden of Disease Study 2023. "All other causes" is a residual (95 causes in 2000; 95 causes in 2023). Percentages are calculated from the death counts shown and may not total exactly 100 because of rounding.

3.3 Current economic burden and the value of the decline

At Rwanda's estimated health-system opportunity cost of US$520 per DALY [6], the 2023 under-five DALY burden of 1,774,367 represents an estimated US$922.7 million in current annual economic burden. The reduction in DALY burden achieved between 2000 and 2023 (3,264,145 DALYs) represents an annual value of approximately US$1.70 billion at the same valuation. In health-opportunity-cost terms, Rwanda's under-five health gains are therefore worth roughly 1.8 times the burden that remains, every year. As a conservative, non-population-adjusted cross-check, the cumulative value of DALYs averted 2001–2023 (holding the year-2000 DALY count constant as counterfactual, ≈ 53.8 million DALYs) is approximately US$28.0 billion. Under the higher, and per § 2.3 less well-justified, GDP-per-capita-multiple convention, the current annual burden ranges from US$949 million (0.5× GDP per capita) to US$5.70 billion (3× GDP per capita), illustrating how sensitive monetised burden estimates are to the choice of valuation threshold (Table 3).

Table 3
Monetised under-five DALY burden under alternative valuation thresholds, 2023

Valuation basis	US$/DALY	Current annual burden	Annual value of 2000 to 2023 decline
Rwanda-specific opportunity cost [6] (primary)	520	$922.7M	$1,697.4M
0.5× GDP per capita	535	$949.3M	$1,746.3M
1× GDP per capita	1,070	$1,898.6M	$3,492.6M
3× GDP per capita	3,210	$5,695.7M	$10,477.9M

GDP per capita, current US$ ≈1,070 (2024) [7]. *Sensitivity rows are shown for comparability with earlier literature and are not the author's preferred estimate (§ 2.3).*

3.4 Modifiable risk factors

Child and maternal malnutrition was the leading risk factor attributable to under-five DALYs in Rwanda in 2023, responsible for an estimated 736,875 DALYs, or 41.5% of the entire under-five disease burden, followed by air pollution (254,309 DALYs, 14.3%) and unsafe water, sanitation and handwashing (150,968 DALYs, 8.5%) (Table 4). At US$520 per DALY, the malnutrition-attributable burden alone is valued at approximately US$383.2 million per year, exceeding Rwanda's reported dedicated stunting/nutrition budget allocation of approximately RWF 357.8 billion (≈ US$245 million at 2026 exchange rates) for FY2024/25 [9], notwithstanding real recent progress: national stunting prevalence fell from 33% (RDHS 2019/20) to 27% (RDHS 2025) [9]. Air pollution and WaSH-attributable burden add a further estimated US$132.2 million and US$78.5 million annually.

Table 4
Top modifiable risk factors for under-five DALYs, Rwanda, 2023

Risk factor	DALYs	% of U5 DALYs	Value, US$M/yr @ $520/DALY
Child & maternal malnutrition	736,875	41.5	$383.2M
Air pollution	254,309	14.3	$132.2M
Unsafe water, sanitation & handwashing	150,968	8.5	$78.5M
Tobacco (incl. secondhand smoke)	11,709	0.7	$6.1M

Source: IHME Global Burden of Disease Study 2023, risk-attributable under-five DALYs.

3.5 Performance relative to development level

Rwanda's SDI rose from 0.288 in 2000 to 0.462 in 2023, remaining in the "Low SDI" quintile throughout. Life expectancy at birth rose from 46.4 years in 2000 to 64.8 years in 2023, a gain of 18.4 years briefly

interrupted in 2020–2021, of which HIV/AIDS, diarrhoeal disease, tuberculosis, malaria and lower respiratory infections were the five largest cause-specific contributors (combined + 12.2 years of the total gain), underscoring how centrally communicable- and child-relevant disease control drove Rwanda's overall health gains. Despite this, Rwanda's 2023 life expectancy (64.8 years) was marginally below the level its SDI would predict (66.5 years; actual-to-expected ratio 0.97), indicating that Rwanda's trajectory since 2000 has brought it to approximate parity with, rather than durably above, its development-level peers, a nuance suggesting that further gains are achievable rather than that the returns to continued investment are exhausted.

3.6 Relation to prior Rwandan under-five mortality research

These GBD-based findings are consistent in direction, though not in data source or method, with a companion analysis of Rwanda DHS data documenting a parallel decline in wealth-based inequality in under-five mortality over 2010–2020 [4]. Together, the two analyses suggest that Rwanda's mortality decline has been both large and increasingly equitably distributed, while, as shown here, leaving a residual burden that remains economically substantial and heavily concentrated in a small number of causes and one dominant modifiable risk factor.

4. Discussion

This analysis provides, to our knowledge, the first monetised estimate of the economic burden and economic value of Rwanda's under-five health transition using internationally comparable Global Burden of Disease estimates. Three findings carry direct policy relevance.

First, the scale of value already created is large by any standard: an estimated 697,800 cumulative deaths averted since 2001, and a burden reduction valued at roughly US$1.70 billion per year at Rwanda's own estimated health-opportunity-cost threshold, a figure that dwarfs typical annual increments to the health budget and provides a quantitative basis for characterising Rwanda's child-survival investments (Mutuelles de Santé, performance-based financing [2], and the national iCCM community health worker platform [3]) as having generated returns that, in health-opportunity-cost terms, compare favourably with almost any alternative use of the same resources. This complements, rather than substitutes for, formal intervention-level cost-effectiveness analyses of those specific programmes, which we did not attempt here.

Second, the remaining burden is not merely large; it is also highly concentrated. Neonatal disorders, a handful of infectious and nutritional causes, and one risk factor (child and maternal malnutrition, 41.5% of all under-five DALYs) account for a disproportionate share of what remains. That the malnutrition-attributable burden (≈ US$383 million/year) appears to exceed current dedicated nutrition financing (≈ US$245 million/year), even as national stunting prevalence has fallen meaningfully from 33% to 27% between the two most recent Demographic and Health Surveys [9], is consistent with, though does not by itself prove, an economic case for further scaling nutrition-specific and nutrition-sensitive investment,

particularly given the documented complementarity between Rwanda's PBF platform and nutrition outcomes [10].

Third, the finding that Rwanda's 2023 life expectancy sits marginally below, rather than above, its SDI-expected level is, we think, appropriately sobering. Narratives about Rwanda's health transformation understandably emphasise the scale of relative improvement since the genocide era; our results confirm that improvement is real and large, but also show that Rwanda has, in absolute terms, only recently reached rough parity with peers at a similar development level, rather than established itself as a positive statistical outlier. This reframes continued investment less as "maintaining an outperformer's lead" and more as "closing a gap that has narrowed but not yet reversed", a framing we consider both more accurate and, if anything, more urgent for domestic and donor decision-making, particularly against a backdrop of substantial recent cuts to development assistance for health globally [1].

Methodologically, we deliberately used Rwanda's own estimated health-opportunity-cost threshold (US$520/DALY) [6] rather than the more familiar GDP-per-capita-multiple convention, because recent empirical work indicates the latter systematically overstates true opportunity costs in low-income settings [5]. We report GDP-multiple valuations only as a sensitivity range (Table 3); readers should treat the roughly six-fold spread between our lower and upper valuations as reflecting genuine, unresolved methodological uncertainty in global health economics, not imprecision specific to this analysis.

Limitations. This is a secondary analysis of modelled GBD estimates, which, like all such estimates, carry cause- and year-specific uncertainty; malaria mortality in particular carries a wide 95% uncertainty interval in the GBD 2023 Rwanda series, and cause-specific findings should be read with this in mind. Our deaths-averted calculation is a standard descriptive counterfactual, not a causal estimate attributable to any specific policy; multiple concurrent health-system reforms make attribution to any single intervention infeasible with these data. Our monetisation rests on a single, if empirically grounded and Rwanda-specific, opportunity-cost parameter, itself drawn from an updated cross-country estimate that has not yet completed peer review [6], and, like all DALY-monetisation exercises, should be read as an illustrative, policy-relevant order of magnitude rather than a precise valuation; we have not discounted or age-adjusted averted deaths, nor incorporated household-level catastrophic health expenditure, both natural and valuable extensions. Finally, this analysis is ecological and national in scope; it cannot speak to subnational or wealth-based distribution of either the burden or its economic value, a gap partly addressed by our companion DHS-based analysis [4].

Future work could extend this analysis with disease-specific burden estimation (for example for diarrhoeal disease, a leading contributor identified here) using primary surveillance or survey data, and could incorporate formal discounting and household-level cost data to move from an opportunity-cost valuation toward a full societal cost-of-illness estimate.

5. Conclusion

Rwanda’s under-five mortality decline since 2000 represents one of the largest health and economic gains achieved by any country over the period: an estimated 697,800 cumulative deaths averted and a burden reduction worth approximately US$1.70 billion annually at Rwanda’s own estimated health-opportunity-cost threshold. Yet a substantial burden persists, valued at roughly US$922.7 million per year and concentrated in the neonatal period and driven overwhelmingly by one modifiable risk factor, child and maternal malnutrition, whose economic burden appears to exceed current dedicated financing. Rwanda’s overall health performance, while transformed since the genocide era, has only recently reached approximate parity with its socio-demographic development peers rather than durably exceeding them. Continued, targeted investment, specifically in neonatal care platforms and in nutrition-specific and nutrition-sensitive programming, is economically justified under Rwanda’s own estimated opportunity-cost threshold and remains a live rather than a completed policy agenda.

Declarations

Clinical trial number

not applicable

Ethics approval and consent to participate:

Not applicable. The study used only publicly available, de-identified, aggregate secondary estimates; no primary data were collected and no ethical approval or informed consent was required.

Consent for publication:

Not applicable.

Conflicts of interest:

The author serves as a GBD Collaborator with IHME; IHME had no role in the design, analysis, or decision to submit this work.

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Author Contribution

J.M.V.N. conceived the study, conducted the analysis, and wrote the manuscript.

Data Availability

All GBD 2023 estimates used are publicly available via the IHME Global Health Data Exchange (GHDx, ghdx.healthdata.org). Analysis code is available from the author on request.

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Figures

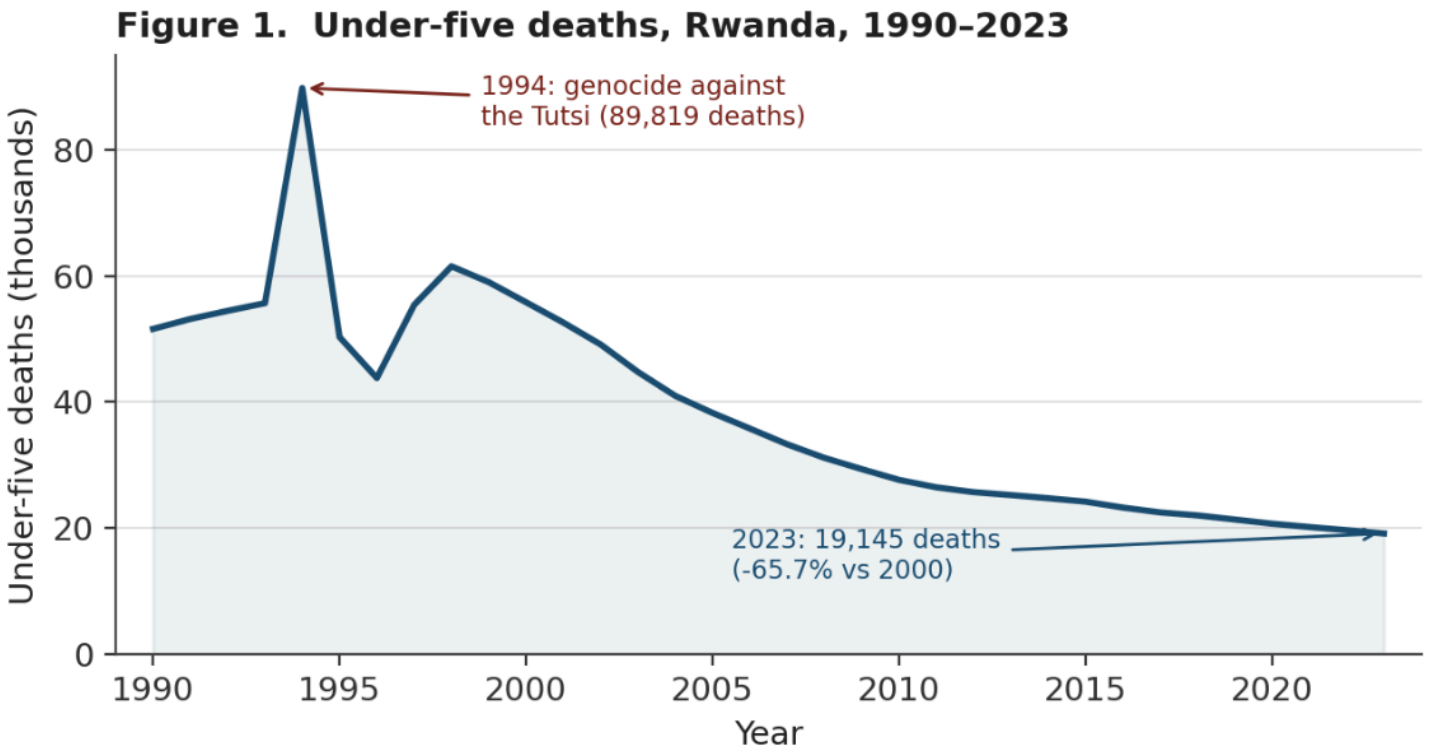


Figure 1

Under-five deaths, Rwanda, 1990–2023. Source: IHME Global Burden of Disease Study 2023.

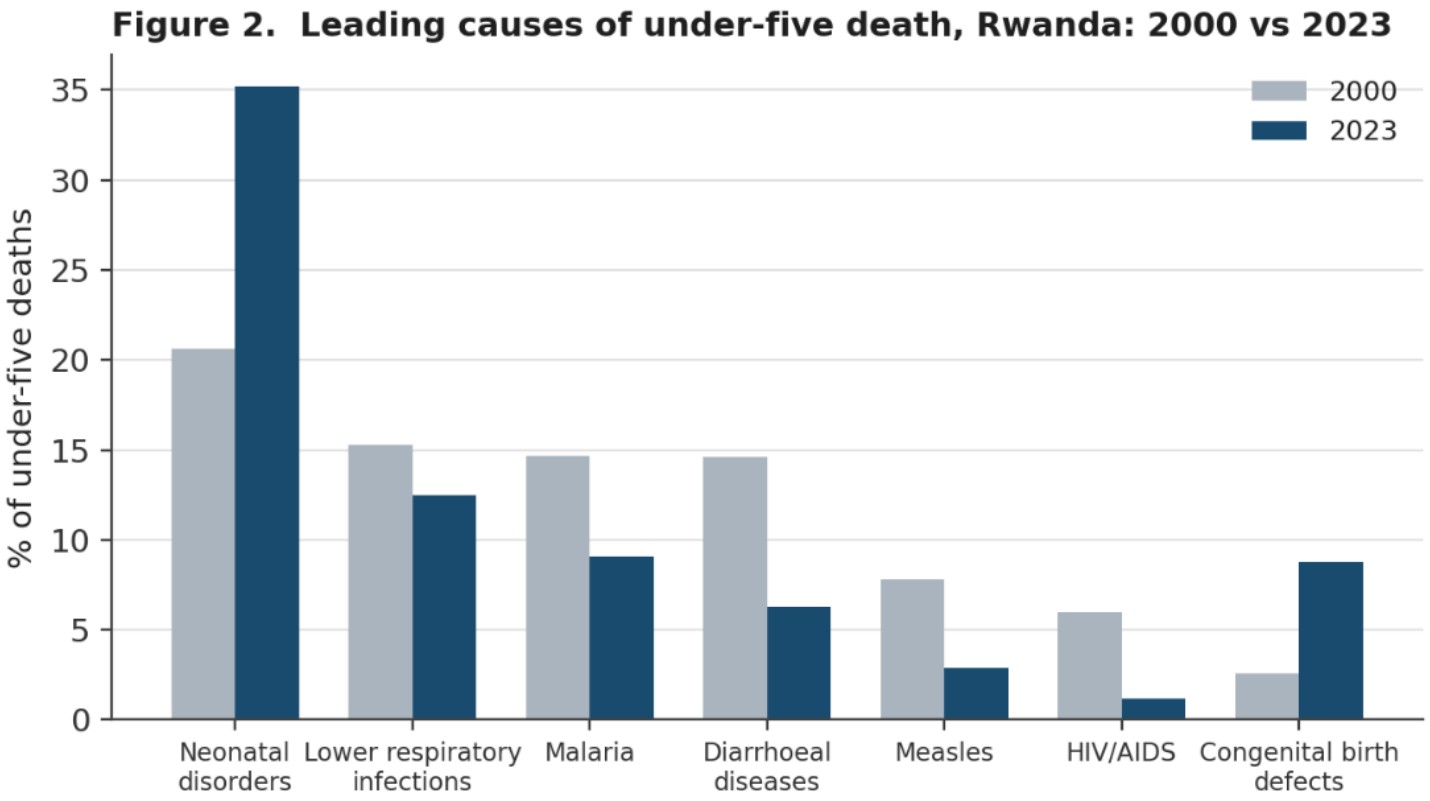


Figure 2

Leading causes of under-five death as a share of all under-five deaths, Rwanda, 2000 and 2023. Source: IHME Global Burden of Disease Study 2023.