What is the association between economic growth and health equity? A cross-national study of 83 low- and middle- income countries

Abstract

Inequities in infant and child mortality are an urgent public health issue for lower and middle income countries (LMICs). We sought to establish whether gross domestic product (GDP) is associated with the extent of health inequalities within LMICs. We conducted a secondary analysis of publicly available health equity data from the Health Equity Database of LMICs, and GDP data from the World Bank. We used infant and under five mortality rates by socioeconomic quintile. The slope of inequality index and relative index of inequality were calculated for both outcomes for each country (N = 83). Linear regression analysis was used to investigate the relationship with GDP. Higher GDP was associated with only a small decrease in absolute socioeconomic inequities in under five mortality (f^2 = 0.10), and was not associated with changes in absolute inequities in infant mortality. Higher GDP was associated with greater relative inequities in infant (f^2 = 0.11) and under five mortality (f^2 = 0.12). Thus, increasing GDP may do little to redress health inequities in infant and under five mortality. Understanding drivers of the

distribution of wealth and income to flatten the socioeconomic gradient in health are crucial to reducing health inequities.

Running head

National income and health inequities

Introduction

Health inequities are systematic inequalities in health caused by unfair distribution of resources or other unjust processes, including unjust distribution of income and wealth, and factors such as racism, and other discrimination.[1] Health equity is a global concern. Health inequities exist *between* countries and *within* countries. In terms of inequities *between* countries, life expectancy is a commonly used indicator of a population's health. There are large global inequities in life expectancy, ranging from Chad with a life expectancy of 52.8, through to Hong Kong with a life expectancy of 85.4[2] – a span of more than 30 years difference driven by inequities in social determinants of health.[3]

A country's life expectancy has long been associated with national income as measured by gross domestic product (GDP): the greater a nation's wealth, in general, the longer its life expectancy. Gains in life expectancy associated

with increased GDP particularly occur amongst low and middle income countries, with life expectancy benefits of a higher GDP subsequently tapering off among richer countries.[4,5] This relationship was demonstrated by Samuel Preston in 1975, and is known as the Preston Curve.[4,5] The research on GDP and life expectancy shows that low and middle income countries (LMICs) have lower life expectancies than higher income countries. Childhood mortality is also higher in LMICs than high income countries, including infant mortality and under five mortality, and this gap is growing.[6] Excess deaths since the onset of the COVID-19 pandemic has been estimated to increase child mortality in LMICs by 3.6%.[7] One of the Millenium Development Goals was to reduce child mortality by two thirds,[8] and this focus remains in the Sustainable Development Goals, with target 3.2 aiming for reductions in neonatal and under five mortality.[9]

Whilst we understand some of the factors that may influence a nation's life expectancy in relation to its wealth,[10,11] there is less research on what factors drive health inequities *within* countries – that is, the *equitable distribution* of a nation's life expectancy, mortality, or other health outcomes.[12] This is particularly the case in LMICs.[13,14] This is all the more urgent because most LMICs are failing to reduce within country health inequities,[15] while health inequities are growing in high income countries including Australia,[16-18] North

America, the UK, and Europe[19] - even before the COVID-19 pandemic further exacerbated health inequities globally.[20-24]

While Jetter and colleagues[5] wrote of the Preston Curve "The predominant medicine for longer lives seems to be raising the level of income per capita", and this emphasis on increasing GDP persists, as evidenced by target 8.1 in the Sustainable Development Goals of "at least 7 per cent gross domestic product growth per annum in the least developed countries".[9] We seek to understand if raising GDP is also the predominant medicine for decreasing health inequities in LMICs, or whether health inequities tend to persist even at higher levels of GDP. The drivers of health equity are different to the drivers of overall health outcomes, as the distribution of social determinants of health, such as income, employment, and housing, within a population is central to understanding health equity outcomes, as well as social inclusion and exclusion processes such as racism, gender inequities, and other discrimination.[25] Thus, as a first step to understanding the drivers of health inequities, our research question was:

> Is there an association between national income (GDP) and the extent of health inequities within a country among low and middle income countries?

Some measures of health are comparable between countries, with life expectancy readily available for almost all countries. Health inequities are

more difficult to compare between countries. There are two main approaches to measuring health inequities within a country in a way that allows comparisons. The first option is to calculate a single measure that captures variation in health among individuals in the population, such as a concentration index – much as is often done to measure the extent of income and wealth inequities.[26] These measures capture the extent of variation in health but not socioeconomic, racial, or other inequities in health.

The second option is a bivariate approach, which looks at the distribution of health along socioeconomic or other inequality lines – for example, examining the relationship between health outcomes and income, level of education, or by geography or race. This generates measures of the extent of inequities such as the Slope Index of Inequality (SII) or Relative Index of Inequality (RII), which measure the social gradient of health within a country. To conduct such bivariate examinations of health inequities between countries however requires both health outcome measures, and socioeconomic or other inequalities measures that are available and comparable across countries.[27]

Beckfield and Krieger [28] in their review found few studies that compared health inequities between countries, and noted that 84% of the studies they found came from high income countries. Only a handful more studies comparing health inequities between countries are evident since their

review.[29-32] Such studies have typically relied on survey data for health and/or socioeconomic measures.[29-31,33] Some studies complement this with register-based mortality data.[29,30] For bivariate approaches to measuring health inequities, there have been a range of socioeconomic measures selected, including education[29], income and wealth.[31,33] This body of work has tracked changes in health inequities over time[34-36] and there has been a particular strand of research that has investigated the effect of different welfare regimes[12,19,28] which has yielded important findings, but also found puzzles, such as the strongest welfare states not having the lowest health inequities as would be expected, that challenge the ease of generating clear findings on inequities.[12]

Three studies were found that had examined the relationship between GDP and health inequities. Eozenou et al.[15] found the concentration indices for under five mortality and stunting were both strongly correlated with real GDP per capita, using data from 91 LMICs for under five mortality and from 102 LMICs for stunting. This paper adds to their paper consideration of SIIs and RIIs to examine absolute and relative inequities, and inclusion of infant mortality measures. Baker et al. [32] calculated the SII and RII for infant mortality for 48 LMICs using longitudinal panel data, and found no evidence of a relationship between infant mortality inequities and GDP, though they did find government expenditure, especially expenditure in non-health

sectors, was associated with lower infant mortality inequities. This research adds to this study updated data, inclusion of under five mortality as well as infant mortality, and a larger dataset of 83 LMICs. Costa-Font and Cowell, using a dataset of 70 LMICs, showed that the relationship between GDP and health inequities varied according to the approach taken to calculating inequities in self-assessed health – varying between a positive relationship, negative relationship, or no relationship.[37] This research adds to that study by repeating the examination using mortality data rather than self-assessed health.

Methods

Health equity data

The most comprehensive data source for comparable within-nation health equity indicators is the World Health Organisation's Health Equity Monitor dataset.[38] The dataset includes infant mortality rates and under-five mortality rates for 92 low and middle income countries (LMICs) calculated from the internationally standardised Demographic and Health Surveys (and for under five mortality, Multiple Indicator Cluster Surveys and Reproductive Health Surveys) conducted in LMICs.[38] Infant and under five mortality are crucial health indicators for LMICs because infant and under five mortality rates in LMICs are 7 and 8 times as high respectively as in high income countries.[39] GDP has been found to be negatively associated with infant and child

mortality rates.[40] There are differences in the determinants of infant and under five mortality. For example, Memon et al.[41] found household wealth predicted neonatal mortality but not under five mortality, while distance to a health facility predicted only under five mortality. Morakinyo and Fagbamigbe noted differences in countries' longitudinal patterns of infant and under five mortality, suggesting they are affected by different factors.[42] Thus, we include both measures in mortality to ensure the influence of GDP on inequities is more comprehensively captured in our analysis. The infant and under five mortality rates in the Health Equity Monitor dataset are expressed as deaths per 1000 live births, and are available by wealth quintile. These quintiles are derived from a household wealth index, descibed by Health Equity Monitor as "Country-specific indices … based on owning selected assets and having access to certain services and constructed using principal component analysis".[38] The health equity data for infant and under five mortality were available for different time points per country. The most recent time point was used for each country, which varied between 1996 and 2019. For 83 of the 92 countries, the most recent time point was between 2010 and 2019. Thus, the 9 countries with a latest time point older than 2010 were excluded from analysis on the grounds that the age of the data made them less comparable.

Gross Domestic Product (GDP) data

GDP per capita data were retrieved from the World Bank.[2] We used GDP per capita converted to constant 2011 international dollars, which adjusts for purchasing power parity, to allow for meaningful comparison between countries. GDP was retrieved for the year matching the year of the most recent health equity data we had available from the Health Equity Monitor and other sources (so if the health data was for 2010 then we used GDP data from 2010). GDP was available for all 83 included countries.

Analysis

We calculated the Slope Index of Inequality (SII, measuring absolute inequities) and Relative Index of Inequality (RII, measuring relative inequities) for infant and under five mortality rates for each country (n = 83). These measures were chosen as they use information from across the socioeconomic gradient, rather than just the top and bottom quintiles.[43-45] Both were calculated because researchers have argued that examining both absolute and relative inequities are important.[29,45,46] Absolute inequities captures the raw difference between rates across the socioeconomic gradient (e.g. the gap in life expectancy between the rich and the poor expressed in years), while relative inequities captures this difference as a proportion of a referent rate (e.g. a rate ratio of mortality comparing the richest and poorest quintiles).[47] They are affected by the overall rate

differently: as mortality rates decrease (as is observed as GDP increases), relative inequities are likely to increase, while absolute inequities are likely to decrease.[46,47] Thus, including both gives a fuller picture of the relationship between GDP and health inequities.

The indexes represent outcomes regressed by quintile rank, to provide an estimation of the extent of inequities across the socioeconomic gradient.[32] Like a regression coefficient, the further the indexes are from zero, the greater the socioeconomic inequities in the outcome.

We followed the method for SIIs and RIIs outlined in McKinnon et al.[45] For each country, SIIs and RIIs were calculated from the socio-economic quintile specific infant and under five mortality rates. We linearly regressed the quintile mortality rates on quintile rank to calculate the SII for each country, then divided the SII by the mean mortality rate for the country to calculate the RII (rather than the approach sometimes used where RII = h(1)/h(0)[44]).

To investigate the relationship between GDP and health equity, four regressions models were conducted on the SII and RII for infant and under five mortality rates. Log GDP was used as the independent variable due to the non-linear nature of GDP. Standard scatter diagrams were used to visual the relationships between health inequity measures and log GDP. Adjusted R-square and Cohen's f^2 effect size[48] were calculated for model goodness of fit. Statistical analysis was performed using Stata version 16.1 (StataCorp, Texas, USA).

As all analyses were conducted on publicly available data sets which used aggregated data, no ethics approvals were required.

Results

The 83 countries spanned low income (n = 24), lower middle income (n = 38), and upper middle income countries (n = 21). They included countries in the World Bank regions of Sub-Saharan Africa (n = 41), Latin America & Caribbean (n = 11), Europe and Central Asia (n = 8), East Asia & Pacific (n = 11), Middle East & North Africa (n = 6), and South Asia (n = 6).

The SII and RII for each included country for infant mortality are shown in Table 1, and for under five mortality in Table 2, along with the mortality rates for the richest and poorest quintiles. In some countries, health inequities were very large – for example, in Nigeria in 2018, the least wealthy quartile had almost twice the rate of infant mortality (78.1 [71.6-84.6]) compared to the wealthiest quintile (39.6 [34.1-45.2]), representing an extra 38 infants dying for every 1,000 live births in the poorest quintile. These inequities were evident at all levels of national income - as an example, Türkiye (Turkey) had the highest GDP in our sample, yet in 2013 Türkiye's infant mortality rate in the lowest wealth quintile (22.6 [15.3-30.0] was almost three times as high as the infant mortality rate in the wealthiest quintile (7.8 [0.0-16.3]).

As suggested in Tables 1 and 2, data did not conform to the expected socioeconomic gradient in mortality for the Maldives, Mozambique, Sierre Leone, or South Sudan (as well as Guinea-Bissau and Tanzania for infant mortality), with mortality rates varying in an unclear pattern across wealth quintiles for these countries on these indicators.

[Insert Tables 1 and 2 about here]

The results of the regression analyses are shown in Table 3. A country's GDP per capita predicted absolute inequities in under five mortality, with a small effect size ($f^2 \geq 0.02$)[48], but did not predict absolute inequities in infant mortality ($p = 0.09$). GDP per capita predicted relative inequities in infant mortality and under five mortality with small effect sizes ($f^2 \geq 0.02$).[48] The higher a country's income, the lower its absolute inequities in under five mortality were, but the higher its relative indexes of inequalities for infant and under-five mortality were on average.

[Insert Table 3 about here]

Scatterplots for SIIs are shown in Figure 1, and the scatterplot for RIIs are shown in Figure 2.

[Insert Figures 1 and 2 about here]

Discussion

Our study yielded three key findings. Firstly, based on our calculations of SIIs of 83 LMICs, we found that social gradients in infant and under five mortality were evident in most countries, and in many cases, inequities were very large. Such extensive within-country health inequities represent a failure to achieve health for all. These inequities highlight the shortcoming of relying on average health measures to compare countries on population health outcomes, as these are liable to hide these critical health inequities. For the few countries where the mortality rates did not follow a social gradient of inequities, mortality rates varied with no clear pattern across quintiles, suggesting lower quality data rather than fewer inequities. That these countries (Maldives, Mozambique, Sierre Leone, South Sudan, as well as Guinea-Bissau and Tanzania for infant mortality) do not have a social gradient seems highly unlikely given what we know of how health gets distributed in a population,[25] and that these are nations with governance concerns, political instability, economic inequities, and/or a history of civil war.

Secondly, we found that among LMICs, a higher GDP was only associated with a small decrease in absolute inequalities in under five mortality, and was not associated with a decrease in absolute infant mortality inequities. This is in contrast to the strong evidence for a higher GDP being associated with greater overall life expectancy, with particularly positive gains amongst

LMICs.[5] This confirms that inequities in infant and under five mortality remain crucial public health issues at all levels of development among LMICs, and that there are important differences between drivers of infant mortality and under five mortality in the population. For example, since Memon et al.[41] found household wealth predicted neonatal mortality but not under five mortality, and health facility access predicted only under five mortality, it is possible that an increased GDP is more able to improve health care access as a determinant of under five mortality, but improving social determinants of health such as household income through a higher GDP is more difficult. More research is required to elucidate such causal pathways.

Thirdly, we did find a positive association between GDP and relative inequities in infant and under five mortality. This association may be an artifact of lower overall infant and under five mortality in countries with higher income – as mortality levels drop, relative inequities mathematically tend to increase.[49] Conversely, absolute inequities tend to decrease,[47] which may contribute to the decrease in absolute inequities we found. Alternatively, our findings may raise concerns about how the benefits of higher GDPs get distributed among the population. If increasing GDP is not leading to substantial reductions in absolute inequities in infant and under five mortality, and is increasing relative inequities, then it is likely that the benefits of a higher GDP are not being distributed in a way that can lead to a

flattening the socioeconomic gradient in health. Our findings add to calls to ensure equity in the distribution of national wealth and income to ensure everyone has the opportunity for good health.[3,50,51]

Reductions in child mortality have been achieved through action on the social determinants of health including household wealth, improvements in water and sanitation, immunisations, and education.[6,52] Technologies in the home such as fuel used for cooking, and refrigeration have also affected child mortality rates, and may improve with country and household wealth.[6,53] Thus, the association we found between absolute inequalities in under five mortality and GDP suggests that increasing national wealth may have led to more equitable distribution of these determinants. The fact that the reduction in inequalities in under five mortality as GDP increased were only modest (f^2=0.10), and were not matched by a reduction in absolute socioeconomic inequities in infant mortality suggests that increasing national wealth has not been distributed as equitably as it could have been, allowing these inequities to continue.

One priority for future research and public health action is to address the lack of available comparable data for high income countries. We were only able to find comparable infant mortality data by socioeconomic quintile for four high income countries. We couldn't find under five mortality by socioeconomic quintile for any high income country. This represents a significant gap in our

knowledge, and makes it impossible to assess progress in reducing infant or under five mortality inequities in most high income countries. It also means we lack global measures of health inequities by socioeconomic status by which to compare all countries – a resource that would allow much investigation of amenable drivers to reduce health inequities through public policy and other strategies. Much could be learned about successful policy settings and approaches from countries that are minimising health inequities, and about deleterious policies and drivers from countries that have higher health inequities.

Limitations of this study

The study was limited by the available data and comprehensive comparative analysis of health inequities between countries would require stronger comparable health inequities data than are currently available. The shortcomings of available data are a key finding in our study. The Health Equity Monitor is a valuable resource, but not sufficient to allow full exploration of health inequities within countries globally.

In addition, the time points for which the Healthy Equity Monitor data was available differed between countries (1996-2019, though the 9 countries with data older than 2010 were excluded from analyses), reducing comparability,

and confidence intervals around the data points were very large. Reducing child mortality has been a goal of the Millennium Development Goals, the Sustainable Development Goals, and the UN Development Program.[6,34] One analysis found that child mortality, and socioeconomic inequities in child mortality, have decreased in lower and middle income countries since the 1990s, while relative socioeconomic inequities in child mortality have remained stable.[34] Improvements in health care systems over time and the progress towards universal health coverage are also likely to improve child mortality and inequities in child mortality.[54]

Lastly, these datapoints pre-date the COVID-19 pandemic, which has highlighted and exacerbated the health inequities that exist in all countries, along gender, socioeconomic, and ethnicity lines, and this has brought renewed urgency to the task of understanding the causes of inequities.[21-24]

Conclusions

Unlike the strong association between a country's income and their overall level of health, in our study of LMICs we found a higher GDP was only associated with a small reduction in absolute socioeconomic inequities in infant mortality, no reduction in absolute socioeconomic inequities in under

five mortality, and an increase in the relative inequities in both mortality categories. Thus, the Preston Curve association found between GDP and life expectancy was not found for health inequities in LMICs,[4,5] suggesting that focusing on raising the GDP of LMICs alone may do little to address inequities in child mortality within countries. These findings indicate that the benefits of a higher GDP may not be being used to develop policies designed to flatten socioeconomic gradients in health. Understanding what country context factors beyond GDP drive absolute and relative health inequities is a critical population health problem and should be theorised and empirically examined further.[10]

Funding Acknowledgements

This work was supported by the Flinders Foundation (no grant number), and the Australian National Health and Medical Research Council Investigator Grant 20099223. CB is funded by a Norwegian Research Council grant (project number 288638).

Declaration of Conflicting Interests

The Authors declare that there is no conflict of interest.

Data Availability

The data underlying this article are available from the Health Equity Monitor[38] and World Bank.[2]

References

1. Braveman P, Gruskin S. Defining equity in health. *Journal of Epidemiology & Community Health*. 2003;57(4):254-258. doi:https://doi.org/10.1136/jech.57.4.254
2. World Bank. Data from: Life expectancy at birth, total (years). 2023. *Washington, DC*.
3. Commission on Social Determinants of Health. *Closing the gap in a generation: Health equity through action on the social determinants of health*. 2008.
4. Preston SH. The Changing Relation between Mortality and level of Economic Development. *Population Studies*. 1975/07/01 1975;29(2):231-248. doi:10.1080/00324728.1975.10410201
5. Jetter M, Laudage S, Stadelmann D. The Intimate Link Between Income Levels and Life Expectancy: Global Evidence from 213 Years. *Social Science Quarterly*. 2019;100(4):1387-1403. doi:10.1111/ssqu.12638
6. Bizzego A, Gabrieli G, Bornstein MH, et al. Predictors of contemporary under-5 child mortality in low-and middle-income countries: a machine learning approach. *International journal of environmental research and public health*. 2021;18(3):1315.
7. Ahmed T, Roberton T, Vergeer P, et al. Healthcare utilization and maternal and child mortality during the COVID-19 pandemic in 18 low-and middle-income countries: An interrupted time-series analysis with mathematical modeling of administrative data. *PLoS medicine*. 2022;19(8):e1004070.
8. World Health Organization. *Millennium Development Goals*. 2004.
9. SDG Fund. Sustainable development goals. https://www.un.org/sustainabledevelopment/inequality
10. Baum F, Popay J, Delany-Crowe T, et al. Punching above their weight: a network to understand broader determinants of increasing life expectancy. *International Journal for Equity in Health*. 2018/08/13 2018;17(1):117. doi:10.1186/s12939-018-0832-y
11. Freeman T, Gesesew HA, Bambra C, et al. Why do some countries do better or worse in life expectancy relative to income? An analysis of Brazil, Ethiopia, and the United States of America. *International Journal for Equity in Health*. 2020;19(1):1-19. doi:https://doi.org/10.1186/s12939-020-01315-z
12. Bambra C. Health inequalities and welfare state regimes: theoretical insights on a public health 'puzzle'. *Journal of Epidemiology & Community Health*. 2011;65(9):740-745.

13. Houweling TAJ, Kunst AE. Socio-economic inequalities in childhood mortality in low- and middle-income countries: a review of the international evidence. *British Medical Bulletin*. 2009;93(1):7-26. doi:10.1093/bmb/ldp048
14. O 'Neil S, Taylor S, Sivasankaran A. Data equity to advance health and health equity in low-and middle-income countries: a scoping review. *Digital Health*. 2021;7:20552076211061922.
15. Eozenou PH-V, Neelsen S, Lindelow M. Child health outcome inequalities in low and middle income countries. *Health Systems & Reform*. 2021;7(2):e1934955.
16. Public Health Information Development Unit. Monitoring Inequality in Australia. Torrens University Australia. Accessed 24/5/22, 2022. https://phidu.torrens.edu.au/social-health-atlases/graphs/monitoring-inequality-in-australia
17. Adair T, Lopez A. Widening inequalities in premature mortality in Australia, 2006-16. *Australian Population Studies*. 2020;4(1):37-56.
18. Flavel J, McKee M, Tesfay F, et al. Explaining health inequalities in Australia: the contribution of income, wealth, and employment. *Australian Journal of Primary Health*. 2022;28:474-481.
19. Kelly-Irving M, Ball WP, Bambra C, et al. Falling down the rabbit hole? Methodological, conceptual and policy issues in current health inequalities research. *Critical Public Health*. 2022:1-11.
20. Baum F, Freeman T, Musolino C, et al. Explaining COVID-19 performance: what factors might predict national responses? *BMJ*. 2021;372
21. Bambra C, Riordan R, Ford J, Matthews F. The COVID-19 pandemic and health inequalities. *Journal of Epidemiology and Community Health*. 2020;74(11):964-968. doi:10.1136/jech-2020-214401
22. Gravlee CC. Systemic racism, chronic health inequities, and COVID-19: A syndemic in the making? *American Journal of Human Biology*. 2020;doi:https://doi.org/10.1002/ajhb.23482
23. Okonkwo NE, Aguwa UT, Jang M, et al. COVID-19 and the US response: accelerating health inequities. *BMJ evidence-based medicine*. 2020;doi:https://doi.org/10.1136/bmjebm-2020-111426
24. Xafis V. 'What is Inconvenient for You is Life-saving for Me': How Health Inequities are playing out during the COVID-19 Pandemic. *Asian Bioethics Review*. 2020;12:223-234. doi:https://doi.org/10.1007/s41649-020-00119-1
25. Marmot M. Social determinants of health inequalities. *The Lancet*. 2005;365(9464):1099-1104. doi:10.1016/S0140-6736(05)71146-6
26. Asada Y, Hurley J, Norheim OF, Johri M. A three-stage approach to measuring health inequalities and inequities. *International journal for equity in health*. 2014;13(1):1-13.
27. Alonge O, Peters DH. Utility and limitations of measures of health inequities: a theoretical perspective. *Global health action*. 2015;8(1):27591.
28. Beckfield J, Krieger N. Epi+ demos+ cracy: linking political systems and priorities to the magnitude of health inequities—evidence, gaps, and a research agenda. *Epidemiologic reviews*. 2009;31(1):152-177.

29. Mackenbach JP, Valverde JR, Artnik B, et al. Trends in health inequalities in 27 European countries. *Proceedings of the National Academy of Sciences*. 2018;115(25):6440-6445.
30. Mackenbach JP, Valverde JR, Bopp M, et al. Determinants of inequalities in life expectancy: an international comparative study of eight risk factors. *The Lancet Public Health*. 2019;4(10):e529-e537.
31. Siddiqi A, Nguyen QC. A cross-national comparative perspective on racial inequities in health: the USA versus Canada. *Journal of Epidemiology & Community Health*. 2010;64(01):29-35.
32. Baker P, Hone T, Reeves A, Avendano M, Millett C. Does government expenditure reduce inequalities in infant mortality rates in low-and middle-income countries?: A time-series, ecological analysis of 48 countries from 1993 to 2013. *Health Economics, Policy and Law*. 2019;14(2):249-273. doi:https://doi.org/10.1017/S1744133118000269
33. Mutangadura G, Gauci A, Armah B, Woldemariam E, Ayalew D, Egu B. Health inequities in selected African countries: Review of evidence and policy implications. *Economic Commission for Africa*. 2007;2009:14-51.
34. Chao F, You D, Pedersen J, Hug L, Alkema L. National and regional under-5 mortality rate by economic status for low-income and middle-income countries: a systematic assessment. *The Lancet Global Health*. 2018/05/01/ 2018;6(5):e535-e547. doi:https://doi.org/10.1016/S2214-109X(18)30059-7
35. Roxo L, Bambra C, Perelman J. Gender Equality and Gender Inequalities in Self-Reported Health: A Longitudinal Study of 27 European Countries 2004 to 2016. *International Journal of Health Services*. 2021;51(2):146-154.
36. Hu Y, van Lenthe FJ, Borsboom GJ, et al. Trends in socioeconomic inequalities in self-assessed health in 17 European countries between 1990 and 2010. *J Epidemiol Community Health*. 2016;70(7):644-652.
37. Costa-Font J, Cowell FA. The measurement of health inequalities: does status matter? *The Journal of Economic Inequality*. 2022;20(2):299-325.
38. World Health Organization. Data from: Health Equity Monitor Database. 2020. *Geneva, Switzerland*.
39. World Bank. World Development Indicators. Accessed 28 Nov, 2022. https://databank.worldbank.org/reports.aspx?source=2&series=SH.DYN.MORT&country=
40. Stuckler D, Basu S, McKee M. Drivers of inequality in Millennium Development Goal progress: a statistical analysis. *PLoS medicine*. 2010;7(3):e1000241.
41. Memon Z, Fridman D, Soofi S, et al. Predictors and disparities in neonatal and under 5 mortality in rural Pakistan: cross sectional analysis. *The Lancet Regional Health-Southeast Asia*. 2023;15
42. Morakinyo OM, Fagbamigbe AF. Neonatal, infant and under-five mortalities in Nigeria: an examination of trends and drivers (2003-2013). *PLoS One*. 2017;12(8):e0182990.
43. Wagstaff A, Paci P, Van Doorslaer E. On the measurement of inequalities in health. *Social Science & Medicine*. 1991;33(5):545-557.

44. Moreno-Betancur M, Latouche A, Menvielle G, Kunst AE, Rey G. Relative index of inequality and slope index of inequality: a structured regression framework for estimation. *Epidemiology*. 2015;26(4):518-527.
45. McKinnon B, Harper S, Kaufman JS, Bergevin Y. Socioeconomic inequality in neonatal mortality in countries of low and middle income: a multicountry analysis. *The Lancet Global Health*. 2014;2(3):e165-e173.
46. Regidor E. Measures of health inequalities: part 2. *Journal of epidemiology and community health*. 2004;58(11):900.
47. Mackenbach JP. Should we aim to reduce relative or absolute inequalities in mortality? : Oxford University Press; 2015. p. 185-185.
48. Cohen J. *Statistical power analysis for the behavioral sciences*. Academic press; 2013.
49. Eikemo TA, Skalická V, Avendano M. Variations in relative health inequalities: are they a mathematical artefact? *International Journal for Equity in Health*. 2009/08/27 2009;8(1):32. doi:10.1186/1475-9276-8-32
50. Pickett KE, Wilkinson RG. Income inequality and health: A causal review. *Social Science & Medicine*. 2015/03/01/ 2015;128:316-326. doi:https://doi.org/10.1016/j.socscimed.2014.12.031
51. Bambra C. *Health divides: where you live can kill you*. Policy Press; 2016.
52. Bishai DM, Cohen R, Alfonso YN, Adam T, Kuruvilla S, Schweitzer J. Factors contributing to maternal and child mortality reductions in 146 low-and middle-income countries between 1990 and 2010. *PLoS One*. 2016;11(1):e0144908.
53. Besnier E, Thomson K, Stonkute D, et al. Which public health interventions are effective in reducing morbidity, mortality and health inequalities from infectious diseases amongst children in low-and middle-income countries (LMICs): An umbrella review. *PLoS One*. 2021;16(6):e0251905.
54. Jacobs C, Musukuma M, Sikapande B, et al. How Zambia reduced inequalities in under-five mortality rates over the last two decades: a mixed-methods study. *BMC Health Services Research*. 2023/02/20 2023;23(1):170. doi:10.1186/s12913-023-09086-3

Tables

Table 1

Slope Index of Inequality (SII) and Relative Index of Inequality (RII) (higher = more unequal) for Infant mortality rate (deaths per 1,000 live births) for each country included.

Year	Country	SII	RII	IMR for Wealth Quintile 5 (richest) – Quintile 1 (poorest) with 95% CIs
	Average	*18.3*	*0.44*	*Q5: 29.0 Q1: 45.5*
	Range	*0.9-55.4*	*0.01-1.57*	*Q5: 0.4 – 78.6 Q1: 11.1 – 88.6*
2015	Afghanistan	27.3	0.55	34.5 [27.1-41.9] - 61.8 [53.8-69.8]
2017	Albania	11.6	1.00	0.4 [0.0-1.1] - 12.0 [3.9-20.2]
2018	Algeria	7.4	0.39	12.8 [6.7-18.9] - 20.2 [16.0-24.5]
2015	Angola	37.9	0.79	24.6 [15.4-33.8] - 62.4 [52.7-72.2]
2015	Armenia	8.1	0.34	4.5 [0.0-10.1] - 12.6 [4.2-21.1]

2019	Bangladesh	17.8	0.28	24.0 [20.0-28.0] - 41.9 [37.4-46.4]
2015	Belize	12.6	1.02	3.2 [0.0-7.2] - 15.8 [5.6-26.0]
2017	Benin	23.9	0.33	39.3 [31.4-47.3] - 63.2 [54.4-72.0]
2010	Burkina Faso	35.1	0.38	53.5 [43.9-63.2] - 88.6 [79.8-97.4]
2016	Burundi	30.7	0.48	35.8 [25.2-46.5] - 66.5 [58.4-74.7]
2014	Cambodia	46.7	0.71	15.6 [10.0-21.1] - 62.3 [49.0-75.5]
2018	Cameroon	24.3	0.36	38.2 [30.5-45.9] - 62.6 [50.9-74.2]
2018	Central African Republic	37.8	0.46	45.1 [36.0-54.2] - 82.9 [69.4-96.4]
2019	Chad	1.0	0.01	62.7 [52.7-72.8] - 63.8 [56.0-71.5]
2015	Colombia	16.5	0.78	5.4 [0.9-9.8] - 21.8 [16.8-26.8]

2012	Comoros	2.7	0.05	34.0 [16.0-52.0] - 36.7 [21.0-52.4]
2017	Congo, Democratic Republic	23.8	0.36	28.5 [17.4-39.5] - 52.3 [43.0-61.6]
2014	Congo, Republic	21.7	0.41	30.7 [21.2-44.2] - 52.4 [47.0-58.4]
2016	Cote d'Ivoire	30.1	0.36	51.7 [41.8-63.7] - 81.8 [73.2-91.2]
2014	Dominican Republic	1.3	0.04	25.9 [16.5-35.4] - 27.2 [21.6-32.9]
2014	Egypt, Arab Republic	18.7	0.43	17.6 [13.3-21.8] - 36.2 [30.2-42.3]
2014	El Salvador	13.6	0.85	10.4 [3.6-17.2] - 24.0 [14.9-33.1]
2014	Eswatini	46.7	0.66	34.3 [20.6-48.1] - 81.1 [60.7-101.4]
2016	Ethiopia	7.6	0.09	54.0 [39.8-68.3] - 61.6 [47.3-76.0]

2012	Gabon	2.3	0.04	40.3 [17.2-63.4] - 42.6 [35.6-49.7]
2018	Gambia, The	16.9	0.42	31.7 [22.3-41.2] - 48.7 [41.0-56.3]
2017	Ghana	1.4	0.03	37.7 [25.2-50.2] - 39.1 [29.3-48.9]
2014	Guatemala	23.7	0.54	17.4 [12.1-22.8] - 41.1 [34.7-47.6]
2018	Guinea	43.1	0.55	34.3 [24.2-44.5] - 77.4 [66.3-88.5]
2018	Guinea-Bissau	8.4	0.17	43.7 [30.6-56.8] - 35.2 [26.6-43.9]
2014	Guyana	7.1	0.21	26.7 [11.0-42.4] - 33.8 [21.4-46.2]
2016	Haiti	14.8	0.20	48.1 [34.1-62.0] - 62.8 [50.4-75.3]
2011	Honduras	12.4	0.49	17.6 [11.1-24.1] - 30.0 [25.3-34.7]

2015	India	36.7	0.65	21.2 [19.7-22.6] - 57.9 [56.6-59.2]
2017	Indonesia	19.6	0.52	19.9 [15.9-24.0] - 39.6 [34.7-44.4]
2018	Iraq	10.7	0.41	13.7 [9.6-17.7] - 24.4 [20.8-28.0]
2017	Jordan	2.5	0.12	15.3 [5.9-24.8] - 17.9 [11.5-24.3]
2014	Kenya	1.3	0.02	38.4 [29.8-46.9] - 39.6 [35.1-44.2]
2018	Kiribati	12.7	0.32	34.3 [18.4-50.3] - 47.0 [33.9-60.1]
2018	Kyrgyz Republic	9.3	0.28	9.9 [5.6-14.3] - 19.2 [9.3-29.1]
2017	Lao PDR	42.4	0.73	17.5 [11.7-23.2] - 59.8 [53.7-66.0]
2018	Lesotho	0.9	0.01	63.9 [36.9-91.0] - 64.9 [49.5-80.2]
2013	Liberia	17.2	0.22	62.2 [45.8-78.6] - 79.4 [68.5-90.3]

2018	Madagascar	15.1	0.24	30.1 [22.0-38.2] - 45.2 [39.3-51.1]
2015	Malawi	3.2	0.04	43.5 [34.9-52.1] - 46.7 [40.7-52.6]
2016	Maldives	9.5	0.46	20.6 [2.8-38.4] - 11.1 [5.9-16.4]
2018	Mali	40.7	0.45	36.8 [29.3-44.3] - 77.5 [66.3-88.7]
2015	Mauritania	14.8	0.31	32.8 [25.7-41.9] - 47.6 [41.7-54.3]
2012	Moldova	17.3	0.95	12.5 [6.3-24.8] - 29.8 [16.1-54.7]
2018	Mongolia	13.4	0.71	10.3 [1.7-18.9] - 23.7 [17.7-29.7]
2015	Mozambique	12.9	0.14	32.1 [19.1-45.1] - 19.2 [10.4-28.0]
2015	Myanmar	55.4	1.05	22.5 [11.3-33.7] - 77.9 [64.0-91.8]
2013	Namibia	28.2	0.67	22.4 [10.9-34.0] - 50.7 [40.2-61.2]
2019	Nepal	17.5	0.32	15.1 [7.3-23.0] - 32.6 [24.8-40.4]

2012	Niger	11.3	0.12	52.4 [42.6-62.3] - 63.8 [54.1-73.4]
2018	Nigeria	38.5	0.49	39.6 [34.1-45.2] - 78.1 [71.6-84.6]
2018	North Macedonia	10.8	0.71	16.7 [0.0-36.8] - 27.4 [7.0-47.8]
2017	Pakistan	23.7	0.33	52.5 [39.6-65.5] - 76.3 [66.0-86.5]
2016	Papua New Guinea	19.6	0.53	27.4 [19.0-35.7] - 47.0 [32.3-61.7]
2016	Paraguay	21.5	1.28	4.5 [0.2-8.8] - 26.0 [16.2-35.7]
2018	Peru	11.3	0.50	10.6 [3.5-17.7] - 21.9 [17.8-26.0]
2017	Philippines	21.6	0.78	9.1 [3.9-14.4] - 30.7 [24.8-36.7]
2014	Rwanda	24.9	0.31	25.0 [18.9-31.1] - 50.0 [41.6-58.3]
2019	Sao Tome and Principe	1.8	0.06	18.3 [6.9-29.7] - 20.1 [10.3-30.0]
2017	Senegal	19.1	0.39	27.3 [18.9-35.7] - 46.3 [40.8-51.9]

2017	Sierra Leone	16.8	0.18	73.5 [62.4-84.6] - 56.7 [50.5-63.0]
2016	South Africa	14.5	0.35	39.8 [9.1-70.5] - 54.2 [40.4-68.1]
2010	South Sudan	13.4	0.2	78.6 [67.5-89.8] - 65.2 [55.9-74.6]
2014	Sudan	25.2	0.47	35.2 [28.7-41.7] - 60.4 [54.1-66.8]
2018	Suriname	7.7	0.44	9.9 [0.4-19.3] - 17.6 [10.7-24.4]
2017	Tajikistan	21.5	0.66	18.0 [12.0-24.0] - 39.5 [30.1-48.9]
2015	Tanzania	13.9	0.18	58.6 [45.7-71.6] - 44.8 [36.0-53.5]
2016	Timor-Leste	15.5	0.36	20.2 [12.1-28.3] - 35.7 [27.1-44.2]
2013	Togo	29.8	0.46	31.6 [22.5-40.7] - 61.4 [52.3-70.6]
2019	Tonga	14.6	1.57	1.1 [0.0-3.2] - 15.7 [3.5-27.9]
2018	Tunisia	16.1	1.12	4.8 [0.7-8.8] - 20.9 [14.0-27.8]
2013	Turkiye	14.9	0.36	7.8 [0.0-16.3] - 22.6 [15.3-30.0]
2019	Turkmenistan	10.6	0.37	21.3 [12.4-30.3] - 32.0 [22.0-42.0]
2016	Uganda	17.1	0.23	39.2 [32.3-46.1] - 56.3 [49.1-63.6]
2013	Vietnam	20.6	0.88	8.4 [3.1-13.7] - 29.1 [18.9-39.2]

2013	Yemen, Republic	20.3	0.36	33.0 [25.8-40.2] -	53.3 [45.7-60.9]
2018	Zambia	2.8	0.04	41.5 [30.2-52.8] -	44.3 [37.0-51.6]
2019	Zimbabwe	23.9	0.43	38.8 [28.6-49.0] -	62.7 [49.8-75.6]

Table 2

Slope Index of Inequality (SII) and Relative Index of Inequality (RII) (higher = more unequal) for Under five mortality rate (U5MR; deaths per 1,000 live births) for each country included.

Year	Country	SII	RII	U5MR for Wealth Quintile 5 (richest) – Quintile 1 (poorest) with 95% CIs
	Average	*30.7*	*0.5*	*Q5: 38.0 Q1: 67.8*
	Range	*1.5-119.4*	*0.02-1.4*	*Q5: 0.4 –113.7 Q1: 14.3-174.8*
2015	Afghanistan	40.6	0.66	39.9 [32.4-47.4] - 80.5 [71.3-89.7]
2017	Albania	13.9	1.05	0.4 [0.0-1.1] - 14.3 [5.6-23.1]
2018	Algeria	9	0.41	13.4 [7.3-19.6] - 22.4 [17.9-27.0]
2015	Angola	63.3	0.83	38.8 [25.4-52.2] - 102.2 [88.1-116.3]
2015	Armenia	10.1	0.36	4.5 [0.0-10.1] - 14.6 [5.8-23.5]
2019	Bangladesh	22.3	0.26	28.2 [24.0-32.5] - 50.6 [45.6-55.5]
2015	Belize	17.7	1.13	3.2 [0.0-7.2] - 20.9 [9.5-32.4]
2017	Benin	47.7	0.38	60.1 [51.1-69.1] - 107.8 [96.0-119.6]

2010	Burkina Faso	78.3	0.42	96.6 [84.0-109.1] - 174.8 [159.9-189.8]
2016	Burundi	67.4	0.66	51.6 [40.9-62.3] - 119.0 [107.5-130.5]
2014	Cambodia	57.7	0.71	18.7 [12.8-24.6] - 76.4 [61.5-91.3]
2018	Cameroon	61.7	0.52	49.0 [39.7-58.3] - 110.7 [95.5-125.9]
2018	Central African Republic	50	0.39	67.9 [55.6-80.2] - 117.9 [100.5-135.3]
2019	Chad	13.8	0.08	91.4 [79.8-103.0] - 105.2 [94.2-116.3]
2015	Colombia	20.3	0.82	6.8 [2.0-11.6] - 27.2 [21.9-32.4]
2012	Comoros	11.9	0.15	40.1 [21.2-58.9] - 52.0 [33.8-70.1]
2017	Congo, Democratic Republic	46.2	0.42	39.8 [26.7-52.8] - 86.0 [74.2-97.8]
2014	Congo, Republic	46.7	0.56	32.1 [22.1-46.3] - 78.7 [72.1-85.9]
2016	Cote d'Ivoire	48.5	0.37	72.9 [60.8-87.2] - 121.4 [109.2-134.8]

2014	Dominican Republic	7.9	0.19	26.4 [17.0-35.7] - 34.3 [28.1-40.5]
2014	Egypt, Arab Republic	22.9	0.43	19.2 [14.8-23.7] - 42.2 [35.9-48.5]
2014	El Salvador	17.5	0.93	13.2 [5.2-21.1] - 30.7 [20.7-40.7]
2014	Eswatini	51.9	0.55	50.8 [27.4-74.1] - 102.6 [81.3-124.0]
2016	Ethiopia	23	0.18	66.7 [52.2-81.2] - 89.7 [71.5-108.0]
2012	Gabon	25	0.33	50.3 [27.1-73.5] - 75.3 [64.1-86.4]
2018	Gambia, The	37.6	0.64	39.1 [29.6-48.6] - 76.6 [64.2-89.1]
2017	Ghana	14.6	0.16	48.2 [31.9-64.5] - 62.8 [51.4-74.2]
2014	Guatemala	36	0.62	20.1 [14.2-25.9] - 56.0 [47.8-64.3]
2018	Guinea	88.5	0.64	44.4 [33.3-55.5] - 132.9 [115.5-150.4]
2018	Guinea-Bissau	1.5	0.02	58.6 [40.4-76.9] - 60.2 [48.2-72.2]
2014	Guyana	8.7	0.23	30.6 [15.1-46.2] - 39.4 [25.9-52.8]
2016	Haiti	34.7	0.32	58.6 [44.0-73.1] - 93.3 [78.7-107.8]
2011	Honduras	18.7	0.58	20.2 [13.0-27.5] - 38.9 [33.9-43.9]
2015	India	50.7	0.68	24.5 [22.8-26.2] - 75.2 [73.5-76.9]

2017	Indonesia	28.6	0.58	23.9 [19.4-28.4] - 52.5 [46.3-58.6]
2018	Iraq	13	0.43	16.3 [11.8-20.9] - 29.3 [25.9-32.8]
2017	Jordan	3.1	0.13	16.3 [6.8-25.8] - 19.4 [12.9-25.9]
2014	Kenya	10.1	0.11	46.6 [37.0-56.2] - 56.7 [51.2-62.3]
2018	Kiribati	25.7	0.47	40.7 [23.8-57.6] - 66.4 [50.6-82.1]
2018	Kyrgyz Republic	10.4	0.26	11.0 [6.6-15.3] - 21.3 [10.9-31.8]
2017	Lao PDR	46.5	0.68	20.5 [14.6-26.4] - 67.0 [61.0-73.1]
2018	Lesotho	3	0.03	80.3 [52.4-108.1] - 83.3 [66.2-100.4]
2013	Liberia	30.4	0.24	99.4 [78.5-120.3] - 129.8 [113.2-146.4]
2018	Madagascar	35.6	0.36	39.1 [29.2-48.9] - 74.6 [64.7-84.5]
2015	Malawi	23	0.18	60.1 [50.6-69.7] - 83.2 [74.8-91.5]
2016	Maldives	7.6	0.32	22.6 [4.4-40.8] - 15.0 [9.1-20.9]
2018	Mali	85.3	0.5	57.3 [47.3-67.2] - 142.6 [127.6-157.6]
2015	Mauritania	27.8	0.45	39.7 [32.4-48.5] - 67.5 [60.3-75.6]

2012	Moldova	17.3	0.82	12.5 [6.3-24.8] - 29.8 [16.1-54.7]
2018	Mongolia	15.6	0.69	14.2 [4.8-23.6] - 29.8 [23.5-36.0]
2015	Mozambique	14.5	0.11	47.6 [28.8-66.4] - 33.1 [20.3-46.0]
2015	Myanmar	72.9	1.13	25.9 [14.3-37.6] - 98.8 [82.7-114.9]
2013	Namibia	36.1	0.59	30.7 [17.0-44.3] - 66.8 [54.6-79.0]
2019	Nepal	20.1	0.28	19.7 [9.4-29.9] - 39.7 [31.1-48.3]
2012	Niger	30.2	0.14	113.7 [98.0-129.4] - 143.9 [129.2-158.5]
2018	Nigeria	119.4	0.81	53.4 [47.2-59.5] - 172.8 [160.6-184.9]
2018	North Macedonia	20	1.17	16.7 [0.0-36.8] - 36.6 [4.4-68.8]
2017	Pakistan	43.6	0.5	56.3 [42.2-70.5] - 99.9 [86.7-113.1]
2016	Papua New Guinea	33.2	0.65	35.9 [26.3-45.6] - 69.2 [51.6-86.7]
2016	Paraguay	25	1.36	4.5 [0.2-8.8] - 29.5 [19.6-39.5]
2018	Peru	12.2	0.42	15.3 [4.3-26.2] - 27.5 [22.9-32.0]
2017	Philippines	30.8	0.78	11.2 [5.5-16.9] - 42.0 [34.5-49.5]

2014	Rwanda	44.4	0.32	40.0 [31.6-48.4] - 84.4 [73.4-95.4]
2019	Sao Tome and Principe	8.9	0.21	18.8 [7.3-30.4] - 27.7 [15.6-39.9]
2017	Senegal	45.8	0.56	30.0 [21.1-38.8] - 75.7 [67.5-83.9]
2017	Sierra Leone	6.6	0.04	101.0 [88.5-113.4] - 94.4 [87.0-101.8]
2016	South Africa	25.8	0.5	41.3 [10.5-72.1] - 67.2 [52.0-82.3]
2010	South Sudan	10.8	0.11	105.0 [93.3-116.8] - 94.2 [83.7-104.8]
2014	Sudan	38	0.51	42.6 [34.5-50.7] - 80.7 [73.6-87.8]
2018	Suriname	10	0.51	10.5 [0.6-20.4] - 20.5 [13.0-27.9]
2017	Tajikistan	26.2	0.65	20.4 [14.3-26.5] - 46.7 [36.2-57.1]
2015	Tanzania	4.9	0.04	72.8 [57.5-88.1] - 77.6 [66.0-89.2]
2016	Timor-Leste	29.7	0.49	25.1 [15.8-34.5] - 54.8 [45.0-64.6]
2013	Togo	74.2	0.65	46.3 [34.9-57.6] - 120.5 [106.6-134.3]
2019	Tonga	14.6	1.44	1.1 [0.0-3.2] - 15.7 [3.5-27.9]
2018	Tunisia	20.5	1.18	5.4 [1.0-9.8] - 25.9 [17.5-34.3]
2013	Turkiye	19.8	0.4	8.1 [0.0-16.6] - 27.9 [20.2-35.6]

2019	Turkmenistan	16.5	0.49	23.1 [13.4-32.7] - 39.5 [28.6-50.5]
2016	Uganda	35.7	0.28	52.6 [44.0-61.3] - 88.4 [79.8-97.0]
2013	Vietnam	26.3	0.85	9.8 [4.4-15.3] - 36.1 [24.4-47.8]
2013	Yemen, Republic	31.3	0.46	37.8 [30.2-45.4] - 69.1 [60.7-77.6]
2018	Zambia	9.1	0.07	57.4 [44.6-70.2] - 66.6 [57.7-75.4]
2019	Zimbabwe	40.1	0.51	51.0 [37.6-64.4] - 91.1 [68.8-113.3]

Table 3

Regression analyses for the relationship between gross domestic product (GDP) per capita, and inequities in infant and under five mortality.

	N	Coefficient (95% CI)	P	Adjusted R^2	f^2
SII (Absolute inequity)					
Infant mortality	83	-2.9 (-6.2 – 0.49)	0.09	0.02	0.02
Under 5 mortality	83	-8.9 (-15 - -3.2)	0.003	0.09	0.10
RII (Relative inequity)					
Infant mortality	83	0.13 (0.05 – 0.21)	0.001	0.10	0.11
Under 5 mortality	83	0.13 (0.05 – 0.21)	0.001	0.11	0.12

Note: Log transformation of GDP

Figure Legends

Fig. 1. Scatter diagram of the relationship between gross domestic product per capita and the slope index of inequality for infant mortality (top) and under five mortality (bottom).

Fig. 2. Scatter diagram of the relationship between gross domestic product per capita and the relative index of inequality for infant mortality (top) and under five mortality (bottom)