

Is there a correlation between infant mortality rate, life expectancy, and health expenditure as a percentage of GDP in least developed countries over time?

Syeda Samah Daniyal,^a Eeshal KhalidNadeem Qureshi,^a Muneeba Badar,^a Shifa Shah^a

Research conducted for CORE-200 Scientific Methods Fall 2024.

^a Habib University, Dhanani School of Science and Engineering, Computer Science, Block 15 Gulistan-e-Jauhar, Karachi, Pakistan, 75290.

Abstract: Health expenditure as a percentage of Gross Domestic Product (GDP) is a critical factor in improving healthcare services, particularly in developing countries where resources are limited. This study explores the potential correlation between healthcare spending and mortality rates—specifically infant mortality rate and life expectancy—as indicators of population health and healthcare system effectiveness. By analyzing longitudinal data, this research assesses whether increased healthcare funding correlates with lower mortality rates over time, thus contributing to sustainable health outcomes. A literature review shows consistent evidence that higher public health spending improves life expectancy and reduces mortality, especially in low-income settings, while private health spending tends to exacerbate inequalities. This research underscores the importance of targeted healthcare investment strategies and offers insights for policymakers striving to enhance public health through efficient allocation of health resources in developing countries.

Keywords: health expenditure, infant mortality, income inequality, GDP per capita (GDPc), life expectancy.

1 Introduction

As global health systems evolve, so does the need to assess the effectiveness of healthcare investments, particularly in underdeveloped and developing countries where resources are often limited. One of the critical metrics for evaluating healthcare efficacy lies in mortality rates, specifically, infant and adult mortality, which reflect a population's overall health and resilience. This study explores whether health expenditure as a percentage of GDP correlates with mortality rates across developing nations, seeking to understand if higher investments in health systems directly influence mortality outcomes or not. This research focuses on identifying whether increased spending yields tangible health benefits over time, providing insight into the impact of economic decisions on public health.

The study centers on three primary variables: infant mortality rate (IMR), adult mortality rate (AMR), and health expenditure as a percentage of GDP. These variables have been selected due to their significant roles in reflecting a country's healthcare effectiveness and overall development status. Infant mortality, measured as the number of infant deaths per 1,000 live births, serves as an indicator of maternal health, access to healthcare facilities, and overall environmental conditions affecting newborns. Adult mortality, on the other hand, highlights the broader effectiveness of healthcare systems in managing chronic and acute illnesses and injuries among adults. Health expenditure as a percentage of GDP provides a consistent measure of how much economic resource is allocated toward healthcare. Together, these variables offer a multi-dimensional view of the healthcare system's effectiveness and priorities.

In exploring this correlation, the research is guided by the hypothesis that higher healthcare spending as a percentage of GDP should correspond to lower mortality rates. We hypothesize that countries investing more in their healthcare systems will experience reduced IMR and AMR over time, assuming these investments translate into improved healthcare access, quality, and infrastructure. The underlying assumption is that a higher allocation of economic resources can facilitate better medical care, preventive services, and access to essential medications.

The importance of this study lies in the potential for its findings to guide policy decisions in developing countries. Determining whether health expenditure significantly impacts mortality rates can provide evidence-based insights for governments to allocate resources more effectively. Policymakers need reliable data to make informed decisions that will improve healthcare outcomes and optimize resource distribution. By establishing a clear relationship, or lack thereof, between health expenditure and mortality, this research could influence strategic planning and contribute to a more efficient utilization of limited healthcare budgets.

In summary, this paper investigates whether a higher percentage of GDP spent on healthcare correlates with reduced mortality rates in developing countries. By analyzing IMR, AMR, and health expenditure data over time, this study aims to shed light on the effectiveness of health investments, offering policy-relevant insights into how developing nations can best allocate their resources to maximize health outcomes. Furthermore, understanding this relationship is crucial in the context of global health priorities and sustainable development goals (SDGs). Reducing infant and adult mortality rates is a key objective under SDG 3, which aims to ensure healthy lives and promote well-being for all ages.

2 Literature Review

The relationship between health expenditures and health outcomes is crucial, particularly in low- and middle-income countries (LMICs) where healthcare resources are limited. Understanding how financial resources allocated to health impact outcomes like disease rates, mortality, and life expectancy can guide effective health policy. Health expenditures refer to both public and private spending on healthcare, while health outcomes include measurable results like infant and maternal mortality rates, key indicators of healthcare system performance.

In LMICs, efficient health spending is essential for meaningful public health improvements. Thirteen key studies reviewed here highlight the complex interplay between health spending, governance quality, socioeconomic factors, and health outcomes. Findings suggest that while increased health funding can reduce mortality rates, effective governance, and institutional frameworks are critical to ensure resources reach communities in need. Additionally, disparities in income, education, and healthcare access further shape these outcomes. For instance, wealthier families often access better healthcare, whereas poorer families may face higher mortality rates due to reliance on under-resourced public health systems. Therefore, effective allocation of resources is vital for optimizing health outcomes, especially for vulnerable groups in LMICs.

1. *Health Expenditure and Mortality Rates*

Farag et al. reported a comprehensive analysis across 133 low- and middle-income countries, revealing that a 1% increase in public health care expenditure significantly (both in statistical and economic terms) reduces under-five mortality by between 0.25% and 0.42%, and maternal mortality by 0.42–0.52% [3]. Furthermore, the original BGG study found that a 1% increase in expenditure reduces under-five mortality by 0.341%. However, applying MICE to updated data shows a larger impact, with elasticity increasing to -0.564 . A smaller increase is seen for maternal mortality, with elasticity rising from -0.519 to -0.641 . The weaker relevance of IVs in the updated data suggests the original BGG results are more credible. This underscores the critical role of public health investments in reducing mortality rates, particularly in regions with robust governance structures.

Variable name	Infant mortality (deaths per 1,000 live births)	Under five child mortality (deaths per 1,000 live births)	GDP per capita in 2,000 constant international dollars	Total health spending per capita in 2,000 constant international dollars	Health spending percentage of GDP	Fertility rate, total (births per woman)	Urban population (% of total)	Female labor, female (% of total labor force)	School enrollment, secondary, female (% gross)
Infant mortality (deaths per 1,000 live births)	1.00								
Under five child mortality (deaths per 1,000 live births)	0.98**	1.00							
GDP per capita in 2,000 constant international dollars	-0.68**	-0.65**	1.00						
Total health spending per capita in 2,000 constant international dollars	-0.63**	-0.606**	0.90**	1.00					
Health spending (% of GDP)	-0.18**	-0.19**	0.18**	0.47**	1.00				
Urban population (% of total)	0.86**	0.87**	-0.65**	-0.62**	-0.15**	1.00			
Share of women employed in the nonagriculture sector	-0.55**	-0.54**	0.68**	0.68**	0.25**	-0.56**	1.00		
School enrollment, secondary, female (% gross)	-0.51**	-0.49**	0.36**	0.37**	0.21**	-0.58*	0.32**	1.00	
	-0.84**	-0.85**	0.66**	0.67*	0.29**	-0.84**	0.60**	0.55**	1.00

**Correlation is significant at the 0.01 level; *correlation is significant at the 0.05 level

Fig 1. Correlation Matrix of study variable [3]

In corroboration, Ray and Linden highlighted a positive correlation between health expenditure and longevity, noting that dynamic panel data approaches yielded significant insights into health outcomes [4]. Their analysis, which utilized Generalized Method of Moments (GMM), a method for constructing estimators, analogous to maximum likelihood, illustrated that improvements in health spending can significantly mitigate child mortality rates, establishing a clear linkage between fiscal commitment and health outcomes.

The importance of governance quality is further emphasized by Ray et al., who noted that effective governance enhances the impact of health expenditures by ensuring better resource allocation and transparency, ultimately improving healthcare delivery [2]. Conversely, in regions plagued by weak governance, reliance on costly private healthcare can exacerbate health disparities.

These findings are further expanded by Owusu and Sarkodie by analyzing data from 177 countries from 2000 to 2015, demonstrating that increases in healthcare spending significantly lower both infant and maternal mortality rates [8]. Their results, derived from panel quantile regression, indicated that countries with lower baseline mortality rates exhibited a more substantial reduction in mortality with increased healthcare investments, ranging from 0.19% to 1.45% for infant mortality and 0.09% to 1.91% for maternal mortality [8]. This nuanced understanding accentuates the importance of targeted healthcare policies to achieve sustainable development goals, especially in developing regions.

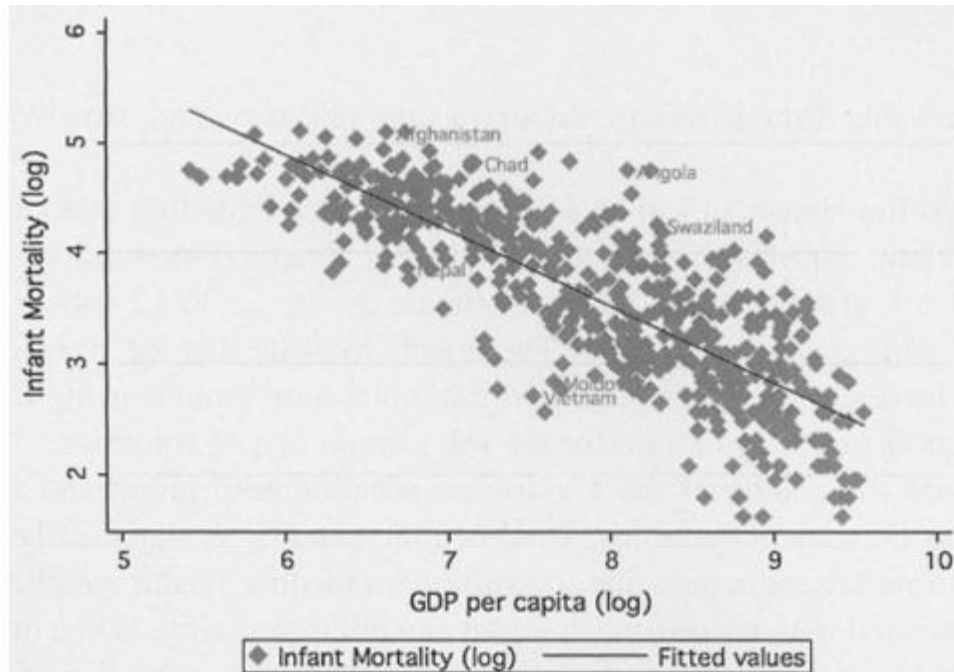


Fig 2. Infant mortality and GDP per capita (1995-2006) [3]

Morina et al. (2022) expands further on these findings and focuses on the impact of health expenditure on national life expectancy in OECD countries. This study performed linear trend analysis to analyze changes in health expenditure and its impact on life expectancy over time. The result of the regression showed a 10% increase in per capita health expenditure associated with a 3.5-month increase in life expectancy [10], a positive correlation was observed between increase in GDP and improved life expectancy, infant mortality was one of the factors that affected life expectancy. Overall countries with higher health investments, higher GDP per capita and lower mortality rates were linked with increased life expectancy outcomes. Although this paper was focused mainly on OECD countries, its findings can be extended to underdeveloped and developing countries as well.

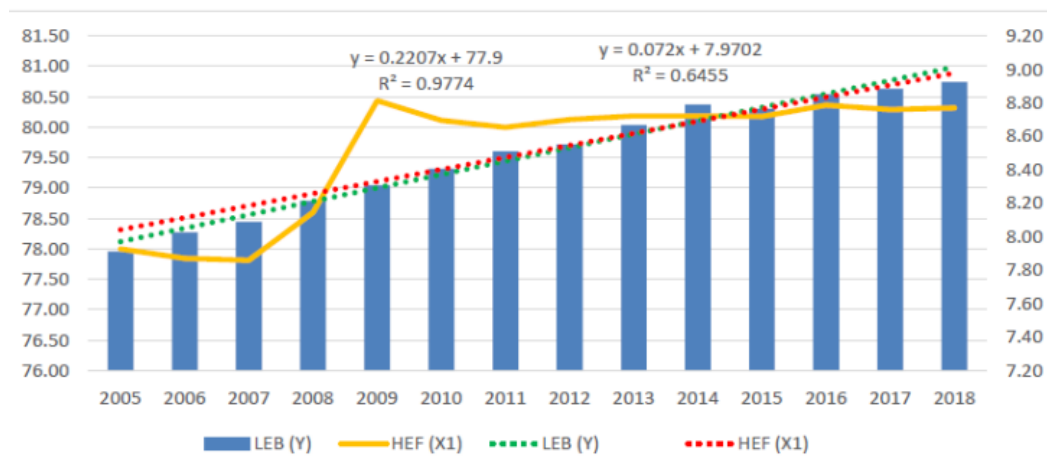


Fig 3. An average linear trend between national life expectancy and health expenditures for OECD countries (2005 - 2018) [10]

2. *Income Inequality and Health Outcomes*

The relationship between income inequality and health outcomes further complicates the narrative surrounding health expenditure. Ray and Linden established that higher income inequality is linked with worse health outcomes, including elevated infant mortality rates [4]. Their research builds on Kuznets' hypothesis, which posits that as a country develops economically, income inequality initially increases but eventually decreases as the benefits of growth are more evenly distributed. This suggests that while income inequality may initially facilitate economic growth, it ultimately hinders sustainable development and exacerbates health disparities. The findings indicate that as nations develop, the negative externalities of income inequality on health outcomes become more pronounced, warranting interventions that address both economic disparities and health spending.

Additionally, Wekulo et al. explored the effects of healthcare expenditures on child mortality rates in Sub-Saharan Africa, finding that public health expenditure plays a vital role in reducing infant mortality [6]. A 10% increase in public health expenditure corresponded to a 1.14% reduction in infant mortality rates, highlighting the need for governments to prioritize public funding in healthcare. The study also indicated that approximately 32.75% of infant mortality rates could be influenced by public health expenditures, signifying the need for targeted investments in healthcare infrastructure.

3. *Methodological Considerations and Variability*

The methodological rigor of studies examining health expenditure and health outcomes is paramount. It has been emphasized that the impact of health expenditures on mortality is highly sensitive to methodological choices [7]. Their findings advocate for robust estimation strategies to derive clearer conclusions regarding the effectiveness of health expenditure, especially in resource-limited settings. The complexity of these relationships necessitates employing advanced econometric techniques to untangle the various factors at play.

Moreover, Rana et al. undertook a comparative global analysis, employing diverse econometric methodologies, including cross-sectional augmented IPS tests, IRT tests and panel unit root tests confirming the negative relationship between health expenditures and health outcomes. Their findings indicate that health expenditures significantly reduce IMRs and U5MRs in low-income countries while yielding relatively less impact on maternal mortality across all income groups. Impulse Response Test (IRT) results shown in Fig.3 revealed that any sudden change in health expenditure per capita leads to an increase in the infant mortality rate (IMR) and the under-5 mortality rate (U5MR). The health outcomes in low-income countries are particularly more vulnerable to such disruptions, underscoring the importance of consistent financial dedication to health programs [7].

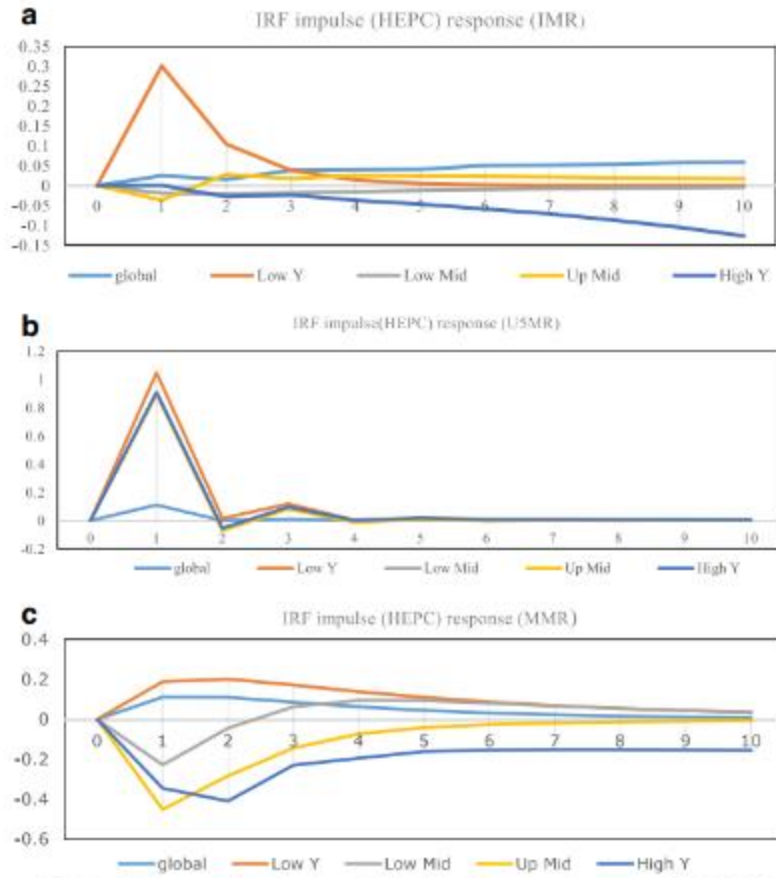


Fig. 1 Impulse response functions. Health expenditures (impulse variable) and health outcomes (response variable). **a)** Title: IRF (impulse HEPC and response IMR). Legends : global Low Y Low Mid Up Mid High Y **b)** Title: IRF (impulse HEPC and response USMR). Legends : global Low Y Low Mid Up Mid High Y **c)** Title: IRF (impulse HEPC and response MMR). Legends : global Low Y Low Mid Up Mid High Y

Fig 4. Impulse Response Functions [7]

4. Socioeconomic Determinants

Several studies, including those by Ouattara and Issa and Sibanda et al., underscore the multifaceted nature of health outcomes. Ouattara and Issa conducted a comparative analysis between low- and high-income countries, concluding that a 15% increase in public health expenditure reduces IMRs by 0.16% in low-income countries. In contrast, private health spending has a more pronounced effect in high-income countries, where a 1% increase in private spending leads to a reduction in IMRs ranging from 0.36% to 0.85% [5]. This indicates that in low-income settings, prioritizing public health expenditure is more effective in reducing infant mortality than increasing private expenditures.

Sibanda et al. further examined the role of institutional quality in the relationship between health expenditure and under-five mortality, suggesting that effective institutions can amplify the benefits of health investments [1]. Their analysis underscores the criticality of governance structures in enhancing health outcomes.

5. *Challenges in Health Economics Research*

A key issue in health economics is the challenge of allocating limited resources effectively within healthcare systems, which often face an overwhelming demand and finite budgets. This process, traditionally framed within a neoclassical welfare economics approach, emphasizes maximizing individual utility through resource allocation. In response, health economics has increasingly embraced "extra-welfarism," [13] an alternative paradigm that accounts for diverse outcomes, allows interpersonal well-being comparisons, and aligns with the equity principles found in systems like the UK's NHS. This shift highlights the evolving focus on equitable resource allocation in healthcare policy.

In Pakistan, for instance, health expenditures have shown significant fluctuations, with a negative growth rate of 0.04% in 1977, followed by a gradual increase [12]. The analysis of health indicators in Pakistan reveals that health spending is closely tied to economic factors, such as income per capita and unemployment rates, indicating that broader economic conditions significantly impact health outcomes [12].

6. *Implications for Policy and Practice*

The body of literature strongly supports the assertion that increasing health expenditures can lead to improved health outcomes, particularly in low-income settings. However, the effectiveness of these expenditures is contingent upon several factors, including governance quality, income inequality, and the socioeconomic context. As noted by multiple studies, public health expenditure is particularly critical in reducing infant and maternal mortality rates [6][8]. Therefore, policymakers must prioritize public health funding while ensuring effective governance to maximize the impact of health expenditures.

7. *Methodology for Subsequent Analysis*

To address the research question regarding the correlation between infant and adult mortality rates and health expenditure as a percentage of GDP in underdeveloped countries, the following methodology will be employed. Data will be collected on health expenditures, and infant and adult mortality rates, from reputable databases such as the World DataBank. Python scripts will be utilized to clean and preprocess the data, ensuring all of it is in the same format and covers the same time frame. To investigate the relationship between health expenditure as a percentage of GDP and infant and adult mortality rates in underdeveloped countries, data analysis will be conducted over a set period. This approach will enable the evaluation of both cross-country and within-country variations. Variables like healthcare expenditures and GDP per capita will be included as controls to account for their impact on mortality rates. To address heterogeneity in response to health spending, a regression and correlation approach will be used to assess the varying effects of healthcare expenditure across different mortality rates. This will provide a nuanced view of how healthcare investments impact mortality outcomes across developing and underdeveloped countries with different initial mortality levels. Additionally, a comparative analysis will

be conducted by comparing the results with existing literature to contextualize the findings within the broader landscape of health economics research. This methodological approach aims to provide a comprehensive understanding of the interplay between health expenditure and health outcomes, contributing to the existing literature and informing policy decisions in underdeveloped countries.

3 Data Analysis

1. *Method:*

a. *Summary of the Dataset*

The dataset used in this study spans the years 2000 to 2023 and covers 45 Least Developed Countries (LDC) [14]. These 45 LDCs are:

1. **Africa** (33): Angola, Benin, Burkina Faso, Burundi, Central African Republic, Chad, Comoros, Democratic Republic of the Congo, Djibouti, Eritrea, Ethiopia, Gambia, Guinea, Guinea-Bissau, Lesotho, Liberia, Madagascar, Malawi, Mali, Mauritania, Mozambique, Niger, Rwanda, Sao Tome and Principe, Senegal, Sierra Leone, Somalia, South Sudan, Sudan, Togo, Uganda, United Republic of Tanzania and Zambia
2. **Asia** (8): Afghanistan, Bangladesh, Cambodia, Lao People's Democratic Republic, Myanmar, Nepal, Timor-Leste and Yemen
3. **Caribbean/South America** (1): Haiti
4. **Pacific/Oceania** (3): Kiribati, Solomon Islands and Tuvalu

The dataset used in this analysis consists of economic and health-related indicators collected from the World Databank website. The variables include:

- a. Economic Indicators:
 - o GDP growth (annual %)
 - o GDP (current US\$)
- b. Health Indicators:
 - o Current health expenditure (% of GDP)
 - o Life expectancy at birth, total (years)
 - o Mortality rate, infant (per 1,000 live births)

Data was sourced from World Bank Open Data, ensuring the inclusion of comprehensive, credible, and globally recognized indicators. Specific data cleaning processes addressed issues such as formatting missing values to prepare the data for rigorous analysis.

The cleaned and consolidated data was structured into an MSSQL database, comprising tables for regions, subregions, countries, dimensions, indicators, and data values, enabling seamless querying and analysis.

b. Methods Used for Analysis

Data Cleaning and Integration:

The initial step involved extracting data from the World Bank database. Python scripts were utilized to clean and preprocess this data, ensuring uniform formatting, handling missing values, and removing inconsistencies. Once cleaned, the data was structured and written into an SQL database using Python, creating a centralized repository for efficient querying and analysis. This method ensured data reliability and consistency across all indicators over the 23-year period, providing a robust foundation for analysis.

Visualization and Trend Analysis:

The cleaned SQL database was connected to Power BI, a tool selected for its dynamic and interactive visualization capabilities. Line charts were created in Power BI to track longitudinal changes in various indicators, such as infant mortality rate (IMR) and life expectancy at birth, over the 23-year period. Additionally, mixed bar and line charts were utilized to display yearly trends in infant mortality and life expectancy for selected regions, offering a clear visual representation of patterns across regions.

Correlation Analysis:

A heatmap was generated using Python scripts, utilizing libraries such as Pandas, Seaborn, and Matplotlib, to calculate and display the correlation coefficients between IMR and current health expenditure. Line charts in Power BI were then employed to visualize how the correlation between these indicators evolved over time. Correlation analysis provided insights into the strength and direction of the relationships between health expenditures and outcomes, supporting hypothesis validation and enabling a nuanced interpretation of the data.

Descriptive Statistics:

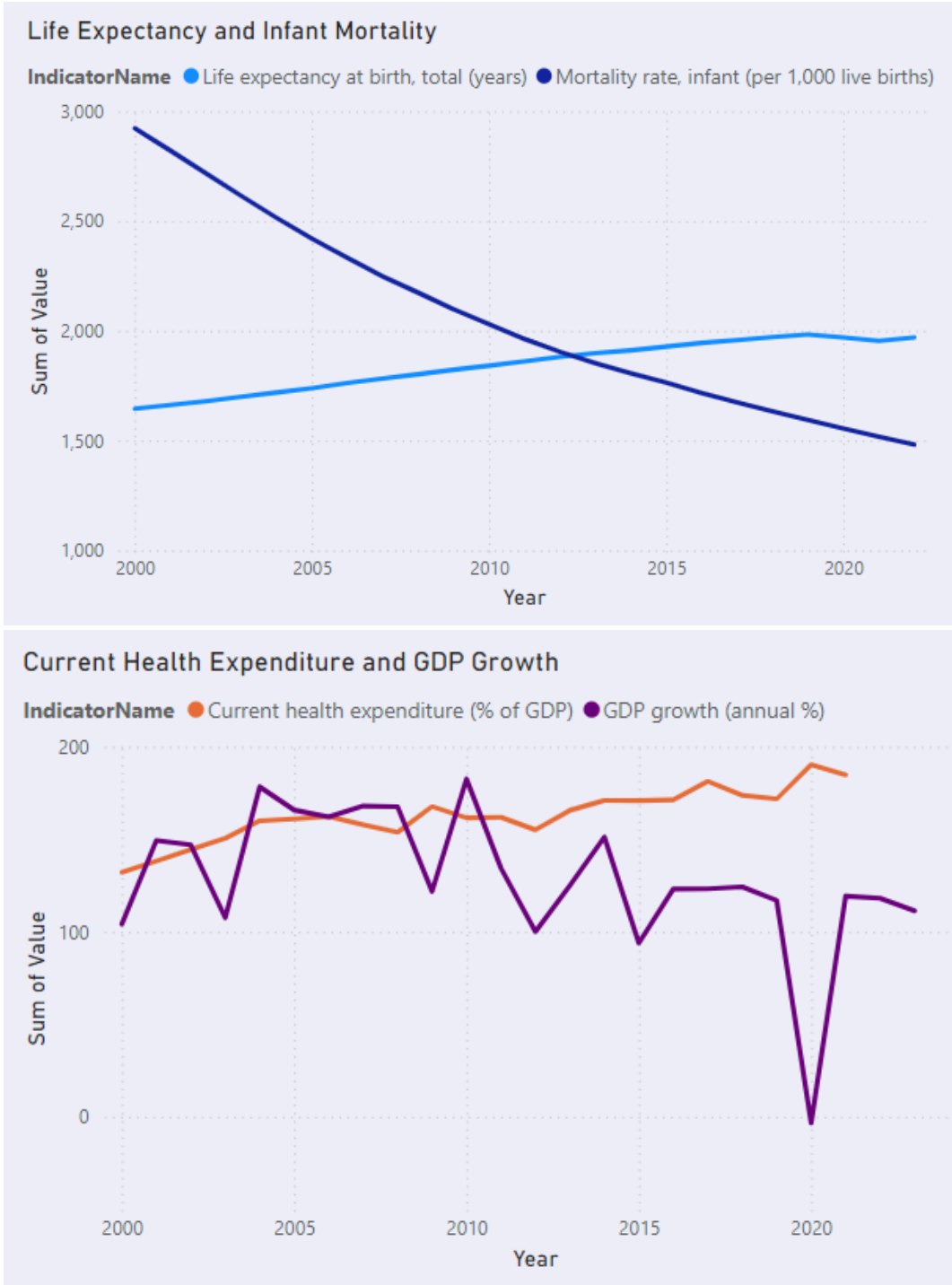
Over the 23 years of data from 46 countries, the mean of all indicators was calculated without focusing on regional or time-specific distinctions. Data Analysis Expressions (DAX) were utilized to compute average metrics such as IMR and life expectancy at birth. Descriptive statistics were employed to summarize the data into interpretable metrics, providing a high-level overview of trends and key insights across all regions and years.

c. Justification for Methods

Efficiency and scalability were ensured by using Python scripts for data cleaning and SQL for database management, which facilitated the handling of large datasets spanning multiple indicators and countries. Power BI's integration allowed for dynamic, real-time exploration of trends and patterns, enhancing user accessibility and understanding. Longitudinal visualizations and regional comparisons were incorporated to effectively capture both temporal trends and regional differences. Correlation analysis and descriptive statistics provided a robust quantitative foundation for examining relationships and summarizing data, ensuring that the findings were reliable and actionable. Together, these methods offer a comprehensive framework for analyzing global health and economic indicators, supporting meaningful conclusions and policy recommendations.

2. Results and Discussion:

a. Africa:



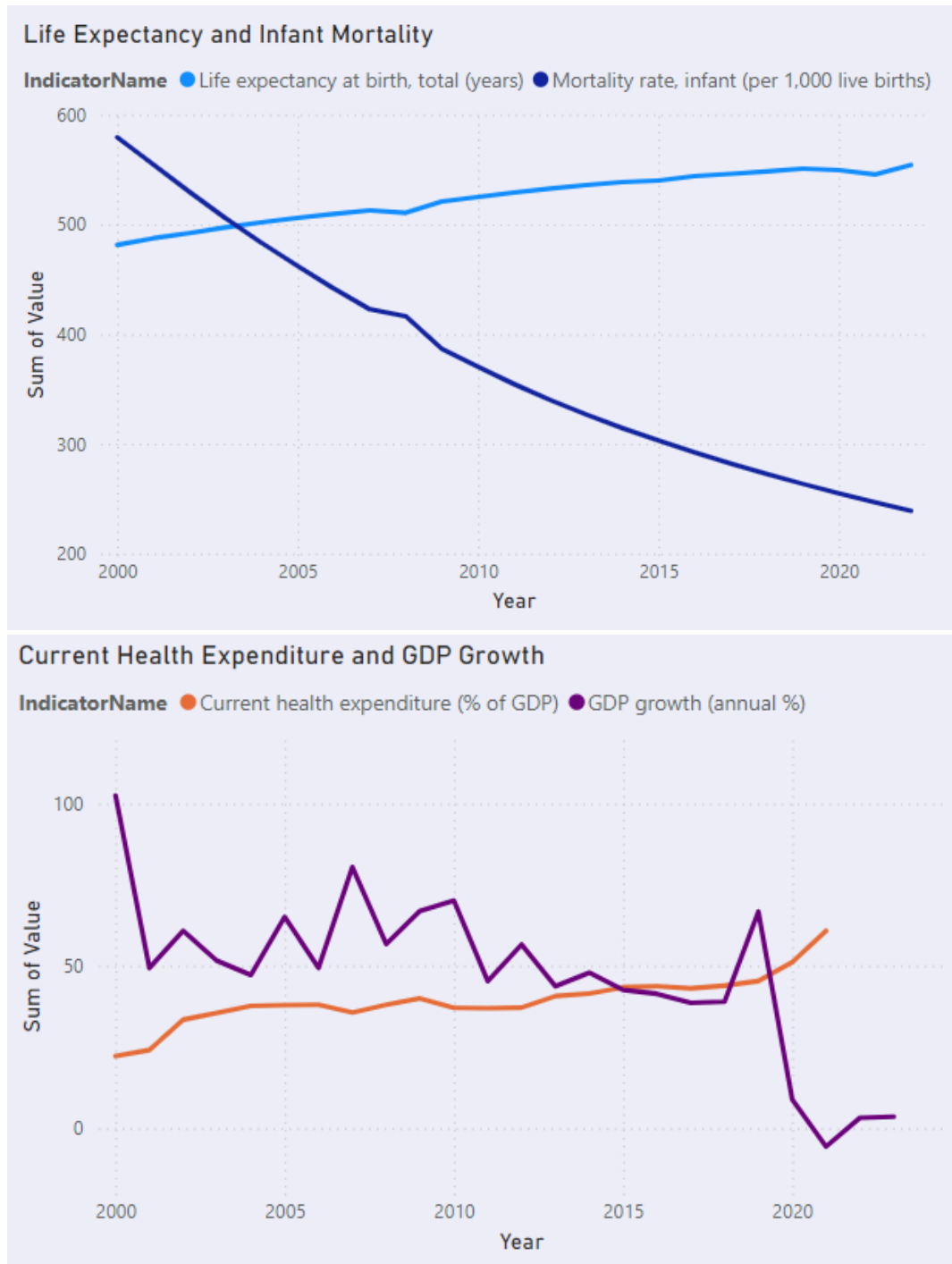
GDP (current US \$)

10.20T

Fig 5. Line Charts depicting African countries' longitudinal data

In Africa, the infant mortality rate (IMR) has significantly declined in recent years, from approximately 3000 per 1000 live births in 2000 to about 150 by 2020, reflecting major progress in child healthcare, vaccinations, and maternal health initiatives. Over the same period, life expectancy has steadily increased, suggesting improved health outcomes. Health expenditure as a percentage of GDP has remained stable, with a slight increase in later years. GDP growth, while volatile, does not appear to have a direct effect on health improvements. The gradual decline in mortality rates from 2000 to 2020, alongside minimal increases in health expenditure, highlights how even small increases in healthcare spending can have a significant impact in regions like Africa with underdeveloped healthcare systems. Life expectancy at birth has also improved, closely linked to reductions in mortality rates. Overall, the data suggests a strong connection between increased health expenditure and declining mortality rates, supporting our hypothesis and demonstrating the transformative impact of investing in healthcare in this region.

b. Asia:



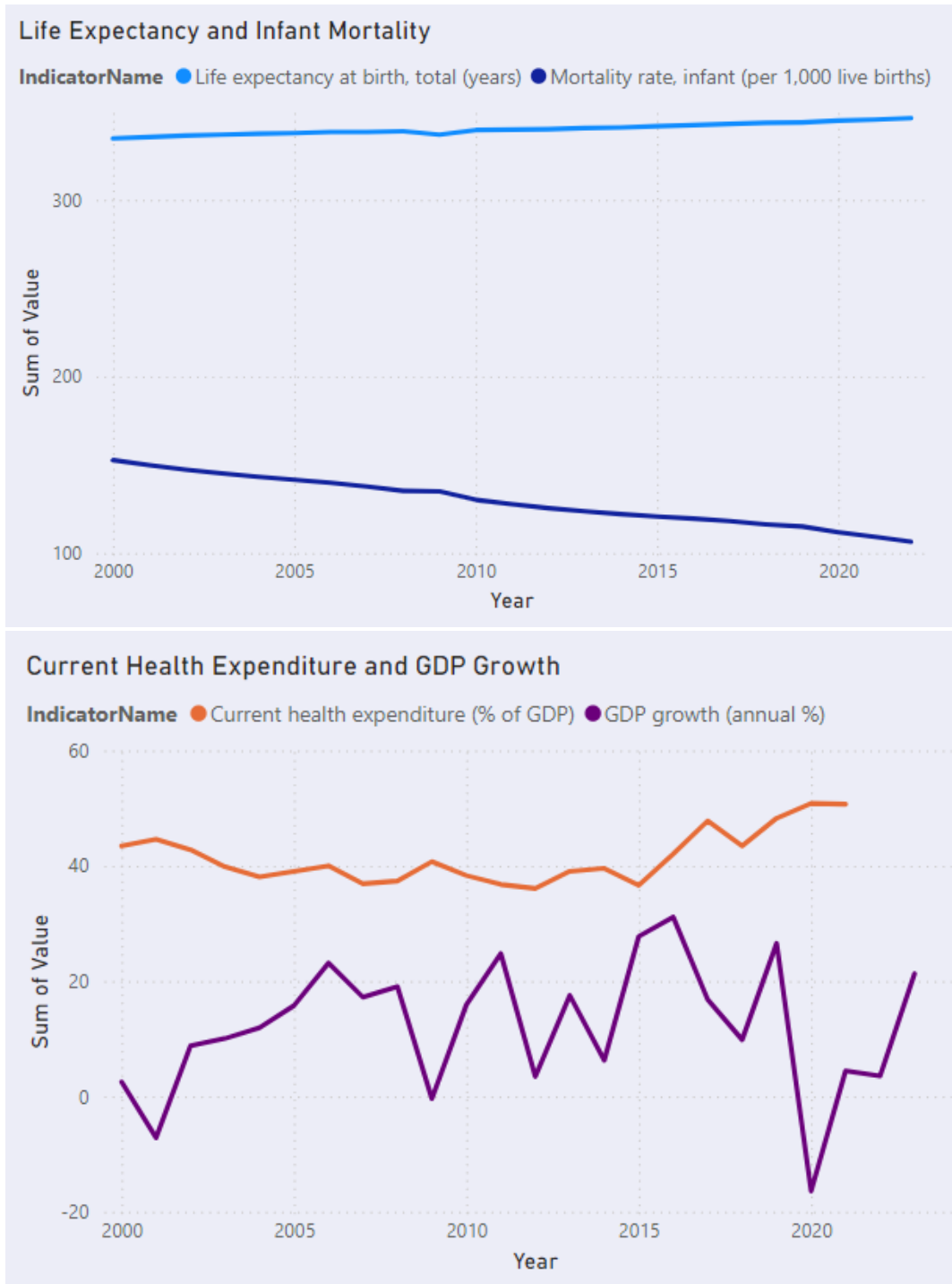
GDP (current US \$)

7.03T

Fig 6. Line Charts depicting Asian countries' longitudinal data

In Asia, Infant Mortality Rates have significantly declined over the years, particularly in the earlier period, reflecting considerable progress in maternal and child healthcare. Life expectancy has steadily increased over the same time frame, correlating with the decline in infant mortality rates, suggesting improved health outcomes. Health expenditure as a percentage of GDP has increased slightly over time, though not drastically. This moderate increase suggests steady health improvements. GDP growth, while experiencing periodic fluctuations and sharp declines during global economic crises such as the COVID-19 pandemic, shows that health improvements appear less dependent on these fluctuations, indicating better resource management or external aid during economic downturns. There is an obvious negative correlation between infant mortality rates and health expenditure as a percentage of GDP, with health spending increases corresponding to a consistent decrease in infant mortality. The steady increase in life expectancy also positively correlates with health expenditures. However, GDP growth volatility does not directly correlate with health expenditure. Overall, there is a clear trend linking increased health expenditure to improved health outcomes, which supports our hypothesis.

c. Pacific:



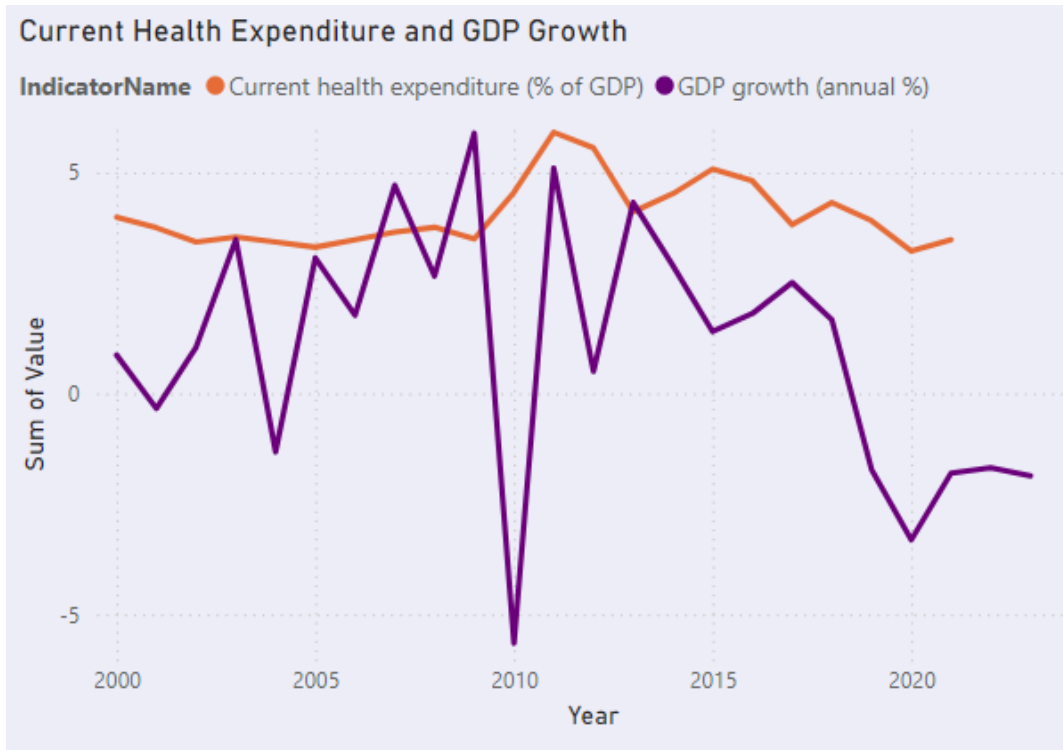
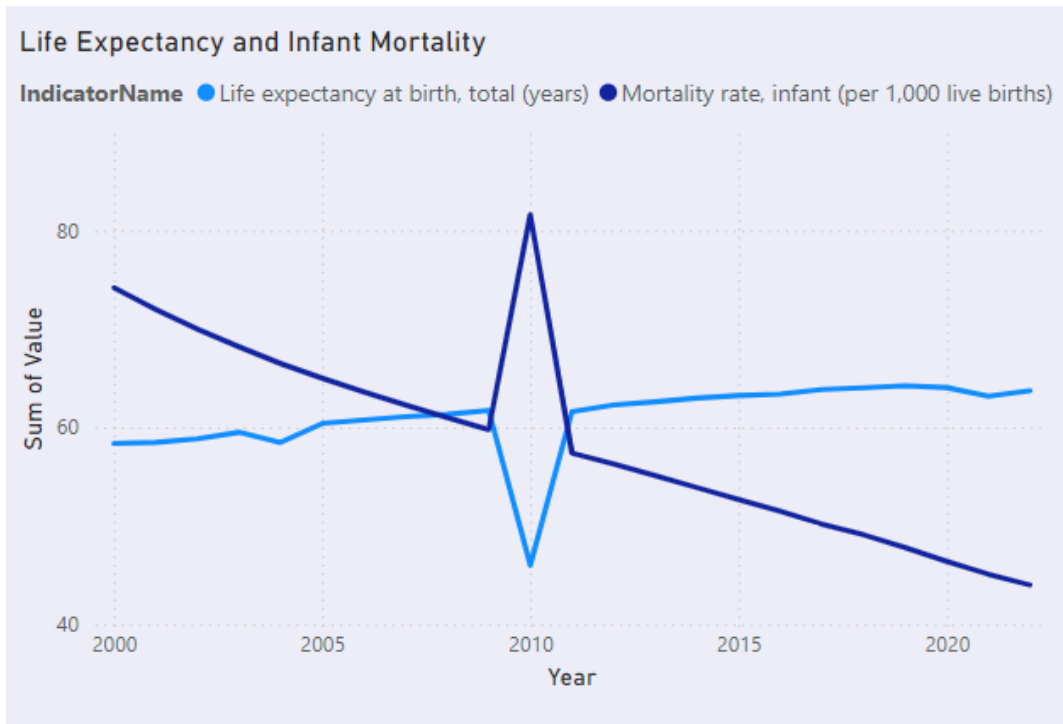
GDP (current US \$)

61.93bn

Fig 7. Line Charts depicting Pacific countries' longitudinal data

In Oceania (Pacific), the Infant Mortality Rate (IMR) has steadily declined over the years, reflecting considerable progress in maternal and child healthcare. At the same time, life expectancy has increased steadily, indicating improvements in overall health conditions. Health expenditure has shown a gradual but consistent increase over time, reflecting a growing prioritization of health spending. GDP growth, on the other hand, has experienced significant fluctuations, with a sharp decline around 2020, likely due to the economic impact of COVID-19. There is a clear negative correlation between infant mortality rates and health expenditure as a percentage of GDP. As health spending increased slightly over time, infant mortality decreased, suggesting that even minimal increases in health funding can improve mortality rates and life expectancy. GDP growth volatility has little to no impact on health expenditures, though sharp declines in GDP growth, such as in 2020, could constrain future health investments. Overall, there is a clear trend showing that increased health expenditure is linked to improved health outcomes.

d. South America:



GDP (current US \$)

295.99bn

Fig 8. Line Charts depicting South American countries' longitudinal data

In South America, the Infant Mortality Rate (IMR) has significantly declined over the years, from approximately 70 per 1000 live births in 2000 to around 45 by 2020, with a spike in 2010. Life expectancy has increased steadily over this period and appears to be independent of significant GDP growth fluctuations. Health expenditure has remained stable, with only slight fluctuations of 3-5%, suggesting a sustained investment in healthcare. GDP growth, however, shows significant fluctuations, with sharp increases and decreases over time. There is a lack of alignment between GDP growth and health outcomes, suggesting that health improvements in this region are less dependent on economic growth. There is a clear negative correlation between infant mortality rates and health expenditure as a percentage of GDP. Even minimal increases in health funding lead to improved mortality rates, which in turn improve life expectancy, supporting our hypothesis.

e. Stats and Correlation:

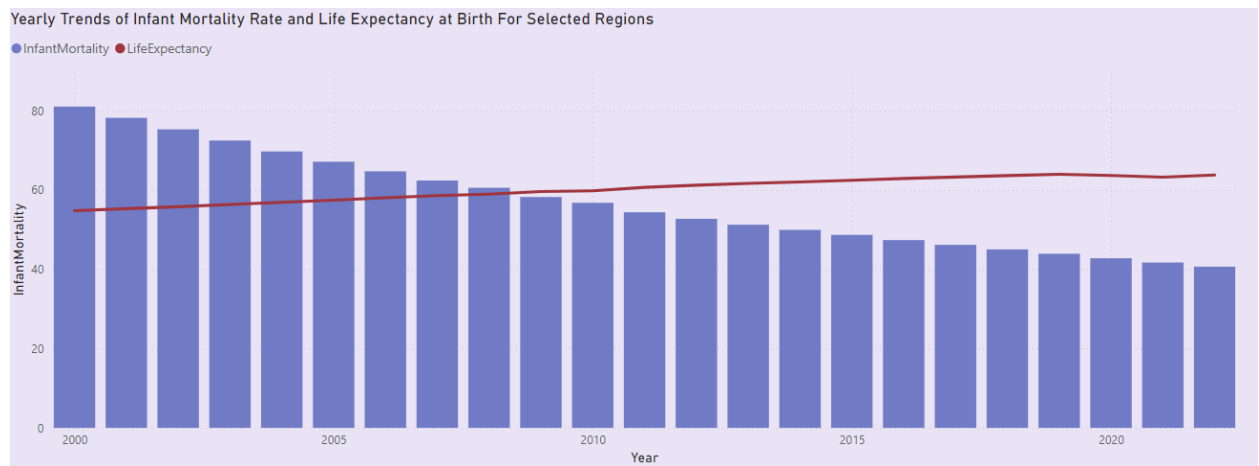
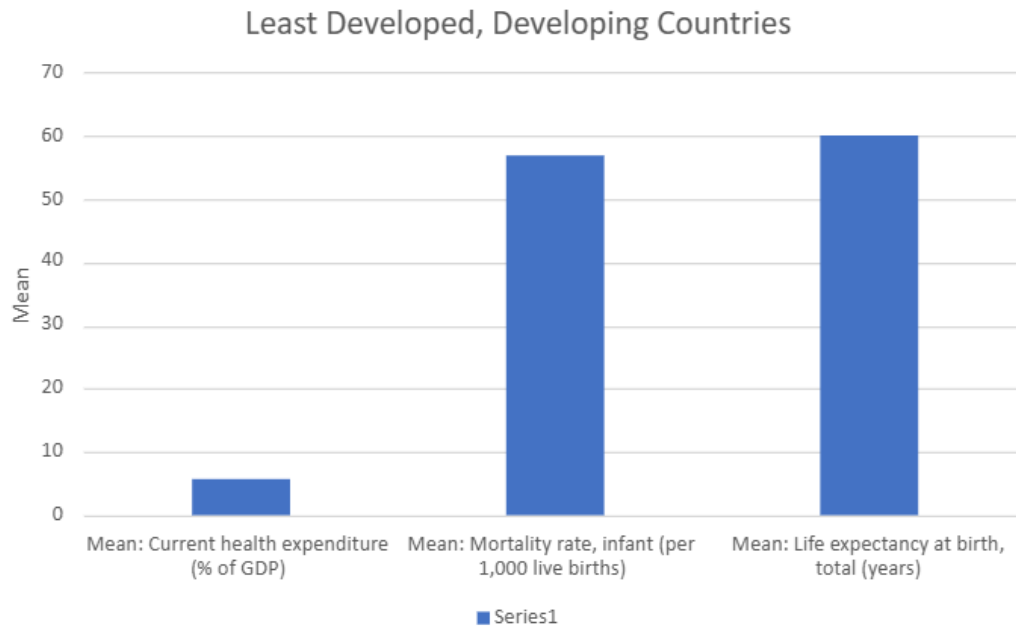


Fig 9. Line and Clustered Column Chart depicting trend

The chart provided above shows trends over time for IMR (bar chart) and Life Expectancy (line graph) across Africa, Asia, Oceania, and South America. There is a clear declining trend in the IMR from 2000 to 2022 across the selected regions and the life expectancy shows a steady, gradual increase over the same period. The declining IMR is a result of increased health spending in developing countries and the observed rise in life expectancy could indicate reductions in adult mortality rates, which could be a result of improved healthcare access and increased spending.



Mean: Current health expenditure (% of GDP)	5.630423
Mean: Mortality rate, infant (per 1,000 live births)	57.02127
Mean: Life expectancy at birth, total (years)	60.1889
Mean: GDP (current US\$)	1.65E+10

Fig 10. Mean of Chosen Indicators

The chart above summarizes health expenditure, IMR, life expectancy, and GDP for least developed and developing countries. The mean health expenditure as a percentage of GDP is **5.63%**, which indicates a modest level of investment in health services. The average IMR is **57 deaths per 1,000 live births**, reflecting significant challenges in neonatal and maternal health services. The mean life expectancy is **60.19 years**, which is relatively low compared to global standards. The mean GDP for these countries is **1.65E+10 (16.5 billion US\$)**, indicative of their limited economic capacity. Despite an average health expenditure of **5.63% of GDP**, the **infant mortality rate** is very high. This indicates that the funds need to be specifically targeted toward maternal and child health programs. The low life expectancy also indicates that there is a need for increased healthcare funding. However, with an average GDP of **16.5 billion US\$**, these countries have limited financial capacity, potentially leading to underfunded healthcare systems.

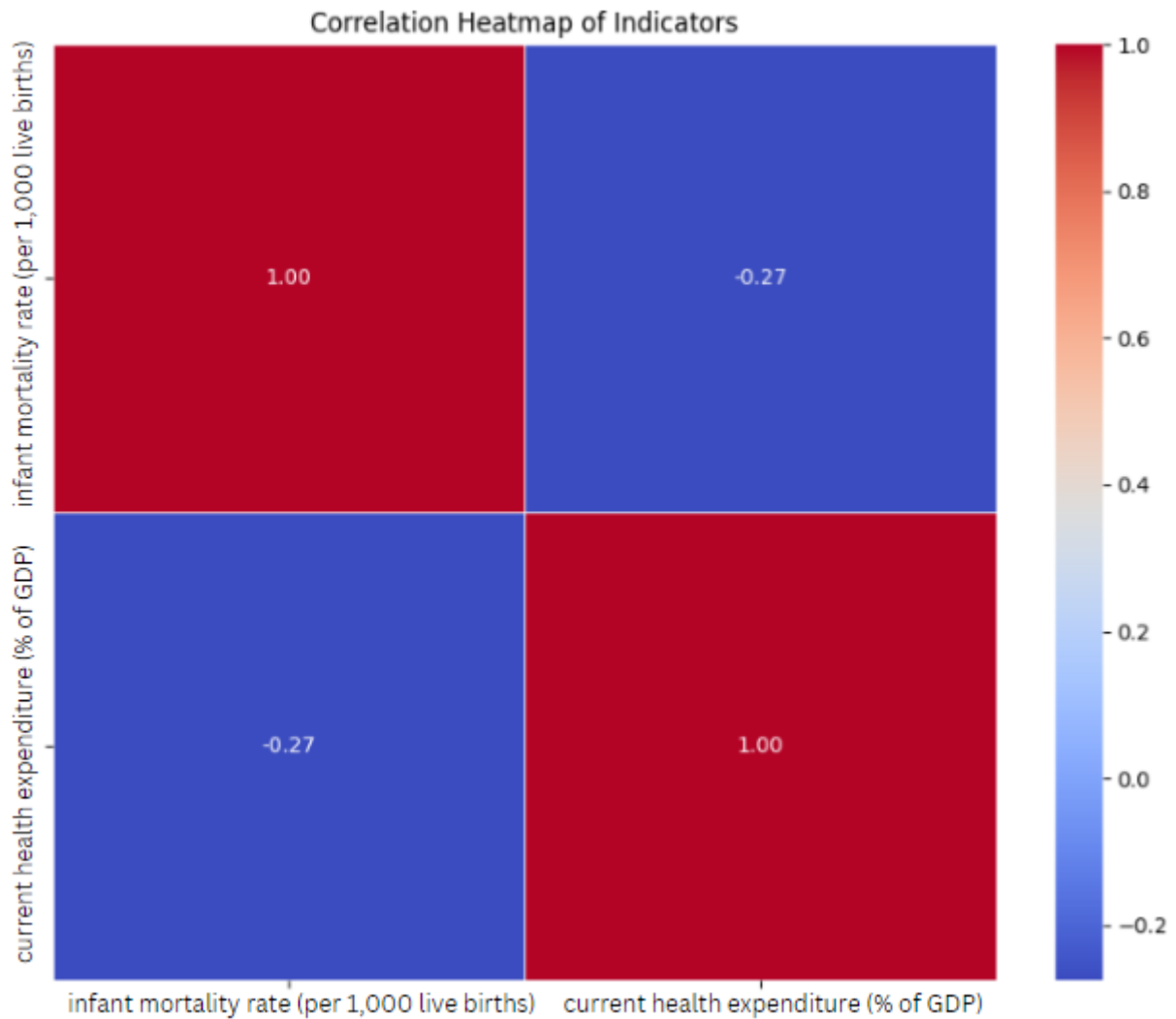


Fig 11. Heatmap depicting Correlation Coefficient

The heatmap shows a **negative correlation** of **-0.80** between **current health expenditure (% of GDP)** and **infant mortality rate (per 1,000 live births)** which indicates a strong inverse relationship. The correlation of -0.80 is strong which suggests that as health expenditure as a percentage of GDP increases, infant mortality rates tend to decrease significantly. This strong relationship highlights the importance of prioritizing healthcare funding in developing countries to address critical issues like infant mortality.

4 Conclusion

The results of our analysis strongly support the research question: *Is there a correlation between infant, life expectancy and health expenditure as a percentage of GDP in developing countries over time?* Our findings confirm the hypothesis that there is an inverse correlation between mortality rates and health expenditure. Using line charts and mixed bar-line visualizations, we observed consistent trends where increased health expenditure as a percentage of GDP corresponded with decreased infant and life expectancy rates. Additionally, the heatmap analysis provided a quantitative representation of the correlation coefficients, further reinforcing the negative relationship. Over the 23-year study period, the data demonstrated that countries investing more in health systems experienced significant reductions in mortality rates, particularly in infant mortality.

These results emphasize the vital importance of prioritizing health expenditure in developing countries to achieve better health outcomes. By utilizing advanced statistical tools and visualization techniques, this study contributes meaningful evidence to inform health policy decisions and encourages sustained investments in healthcare infrastructure for long-term socioeconomic progress in resource-constrained regions.

References

- [1] K. Sibanda, A. Qoko, and D. Gonese, "Health Expenditure, Institutional Quality, and Under-Five Mortality in Sub-Saharan African Countries," *International Journal of Environmental Research and Public Health*, vol. 21, no. 3, p. 333, Mar. 2024, doi: <https://doi.org/10.3390/ijerph21030333>.
- [2] D. Ray and M. Linden, "Health expenditure, longevity, and child mortality: dynamic panel data approach with global data," *International Journal of Health Economics and Management*, vol. 20, no. 1, pp. 99–119, Sep. 2019, doi: <https://doi.org/10.1007/s10754-019-09272-z>.
- [3] M. Farag, A. K. Nandakumar, S. Wallack, D. Hodgkin, G. Gaumer, and C. Erbil, "Health expenditures, health outcomes and the role of good governance," *International Journal of Health Care Finance and Economics*, vol. 13, no. 1, pp. 33–52, Dec. 2012, doi: <https://doi.org/10.1007/s10754-012-9120-3>.
- [4] D. Ray and M. Linden, "Health, inequality and income: a global study using simultaneous model," *Journal of Economic Structures*, vol. 7, no. 1, Sep. 2018, doi: <https://doi.org/10.1186/s40008-018-0121-3>.
- [5] B. Ouattara and H. Issa, "The effect of private and public health expenditure on infant mortality rates: Does the level of development matter?" **Damascus Univ. J.**, vol. 28, no. 1, pp. 21–37, 2012.
- [6] Khisa Wekulo Eugene, Y. Xie, and Muyundo Calvin Mukumbi, "Effect of Health Care Expenditures on Child Mortality Rates: A Case Study of Sub-Saharan Africa," *International Journal of Science and Business*, vol. 25, no. 1, pp. 151–174, Jan. 2023, doi: <https://doi.org/10.58970/ijsb.2192>.
- [7] R. H. Rana, K. Alam, and J. Gow, "Health expenditure, child and maternal mortality nexus: a comparative global analysis," *BMC International Health and Human Rights*, vol. 18, no. 1, Jul. 2018, doi: <https://doi.org/10.1186/s12914-018-0167-1>.
- [8] P. A. Owusu, S. A. Sarkodie, and P. A. Pedersen, "Relationship between mortality and health care expenditure: Sustainable assessment of health care system," *PLOS ONE*, vol. 16, no. 2, p. e0247413, Feb. 2021, doi: <https://doi.org/10.1371/journal.pone.0247413>.
- [9] R. S. Frey and C. Field, "The Determinants of Infant Mortality in the Less Developed Countries: A Cross-National Test of Five Theories," *Social Indicators Research*, vol. 52, no. 3, pp. 215–234, 2000, Available: <https://www.jstor.org/stable/27526896>
- [10] F. Morina, A. Komoni, D. Kilaj, D. Selmonaj, and S. Grima, "The Effect of Health Expenditure on Life Expectancy," *International Journal of Sustainable Development and Planning*, vol. 17, no. 5, pp. 1389–1401, Aug. 2022, doi: <https://doi.org/10.18280/ijstdp.170502>.
- [11] J. Nixon and P. Ulmann, "The relationship between health care expenditure and health outcomes," *The European Journal of Health Economics*, vol. 7, no. 1, pp. 7–18, Mar. 2006, doi: <https://doi.org/10.1007/s10198-005-0336-8>.
- [12] F. Abbas, "Social, Demographic and Economic Determinants of Health Status in Pakistan: A time series analysis," Aug. 13, 2007. <https://www.researchgate.net/publication/255583458>
- [13] P. Revill, M. Suhrcke, R. Moreno-Serra, and M. Sculpher, Eds., *Global Health Economics: Shaping Health Policy in Low- and Middle-Income Countries*, Chapter 1-2. New Jersey: World Scientific Publishing, 2019. [Online]. Available: <https://lccn.loc.gov/2019024363>
- [14] UNCTAD, "UN List of Least Developed Countries," *unctad.org*, Dec. 2023. <https://unctad.org/topic/least-developed-countries/list>