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*Code and data are available at: [https://github.com/Junbo345/Mortality_analysis].

1 Introduction

Over the past 30 years, advancements in society and technology have significantly reduced global mortality rates, particularly for children under the age of five. The under-five mortality rate declined from 93 deaths per 1,000 live births in 1990 to 37 deaths per 1,000 live births in 2022 (Arel-Bundock (2022)). This progress represents millions of children who now have better chances of survival, marking a substantial achievement in global health.

In this study, we examined the under-five mortality rate for each country in 2022, focusing on three key factors: food production index, DPT vaccine coverage, and per-capita health expenditure. These factors were chosen because they reflect critical components influencing child mortality. Infectious diseases, such as pneumonia, diarrhea, and malaria, remain leading causes of under-five deaths, and these are directly linked to vaccination coverage and healthcare spending. Similarly, maternal health during childbirth is influenced by healthcare accessibility and quality, which is often tied to national health expenditures (World Health Organization (2024)). While food production does not directly address infectious disease or maternal health, it reflects a nation's ability to meet nutritional needs, which is critical for preventing malnutrition—a major underlying cause of child deaths (add supporting explanation and citation).

Our findings reveal that increasing vaccine coverage and per-capita health expenditures significantly reduces under-five mortality rates. However, food production index does not exhibit a direct impact, suggesting that its role is mediated by other factors such as distribution systems and food quality. Despite progress in reducing global mortality, the pace of reduction has slowed considerably since 2015, decreasing from an annual rate of 3.8% during the Millennium Development Goal (MDG) era (2000–2015) to 2.1% during the Sustainable Development Goal (SDG) era (2015–2022) (UNICEF (2022)). In 2022 alone, 4.9 million children under the age of five died, equating to approximately 13,400 deaths per day (UNICEF (2022)).

Furthermore, the distribution of under-five mortality rates remains highly uneven. Developed countries such as Canada and the United States report mortality rates as low as 10 per 1,000 live births, while developing nations—particularly in sub-Saharan Africa—experience rates exceeding 100 per 1,000 live births (Arel-Bundock (2022)). This disparity highlights the urgent need for targeted interventions in high-mortality regions. The factors studied in this paper, such as vaccination and healthcare spending, are actionable and can be effectively improved in these regions through foreign aid and international collaboration.

The remainder of this paper is organized as follows. Section 2 describes the data sources, key variables, and preprocessing steps, including transformations applied to address skewness and improve model validity. Section 3 outlines the modeling approach, including the choice of predictors, justification of the model structure, and Bayesian implementation. Section 4 presents the results of the analysis, highlighting the effects of each predictor on under-five mortality. Finally, Section 5 discusses the implications of the findings, the limitations of the study, and recommendations for future research and policy interventions aimed at reducing child mortality globally.

1.1 Estimad

The primary estimand of this study is the effect of three predictors—food production index, vaccination coverage (DPT vaccine percentage), and per-capita health expenditure (log-transformed)—on the logarithm of the under-five mortality rate for each country in 2022. This analysis seeks to quantify the extent to which these factors contribute to variations in mortality rates across nations. By addressing these relationships, the study aims to identify potential intervention points for reducing preventable child deaths and achieving progress toward the Sustainable Development Goals for child survival.

2 Data

2.1 Overview Check packages

For this analysis, we combined four data sets all together into one. All these four data sets comes from **Worldbank** open data platform (Arel-Bundock (2022)). We employed **R** (R Core Team (2023)), a coding platform to download, clean and conduct statistical analysis. Besides, we also utilized R packages **tidyverse** (Wickham et al. (2019)), **rstanarm** (Goodrich et al. (2022)), **ggplot2** (Wickham (2016)), **knitr** ((**knitr?**)), **arrow** (Richardson et al. (2024)), **here** (Müller (2020)), and **dpylr** (Wickham et al. (2023)). The paper is outlined in github using starter folder provided in **Telling Stories With Data** (Alexander (2023)).

2.2 Measurement

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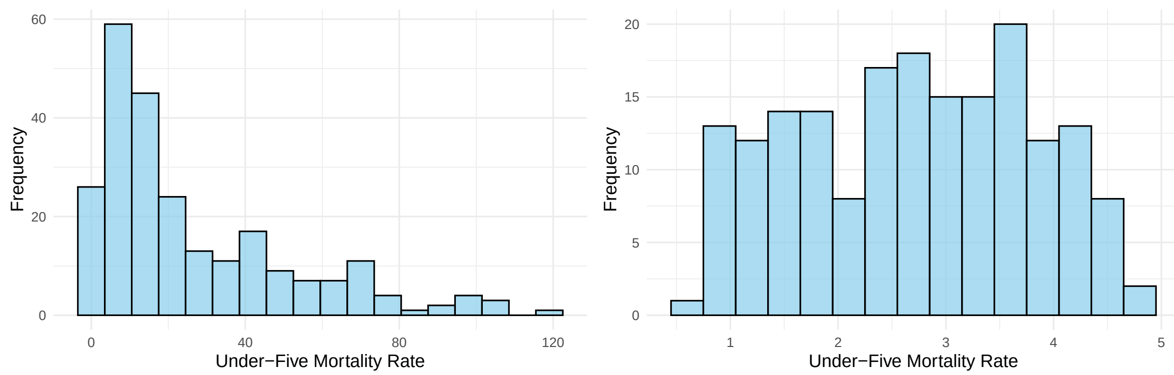
2.3 Outcome variables

The response variable in our analysis is the mortality rate below 5 year-old children for all countries. Here Mortality rate is calculated based on number of deaths of children under 5 years old per 1000 person. The histogram of this variable is shown in Figure 1a. We observe that the data ranges from 0 to 120, with a peak at 10-15.

However, this data is extremely right skewed and have several outlyers, thus we decided to perform log transformation to stabilize the variance and in-proving the normality of our dataset for a better regression model latter. The distribution after we perform log transformation is shown in Figure 1b, here the distribution is approximately normal ranging from 2 to 5 with a peak at 3.



(a) Dsitribution before log tranformation

(b) Distribution after log transformation

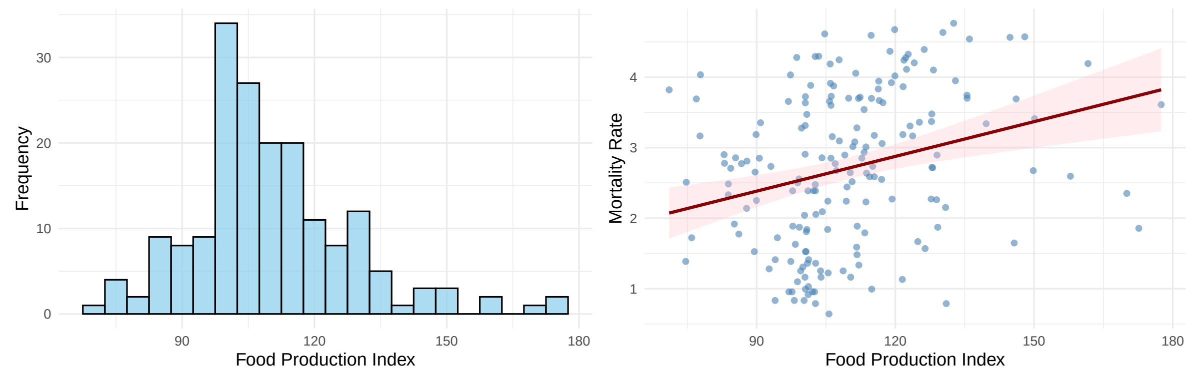
Figure 1: Data Analysis for Mortality Rate of Different Countries

2.4 Predictor variables

In our mdoel, we have three Preditor variables, namely, Food production index, which is the relative level of agricultural production for each nation compared with the base period 2014-2016 (Arel-Bundock (2022)); Current health expenditure per capita (current US$); and DPT vaccine percentage.

We will first look at the food production index. From Figure 2a, we see that it ranges from 60 to 180, with a center at 110, and the shape is approximated normal distributed. Figure 2b is the scatter plot between Food production index and log of Mortality rate, with a best line of fit and standard error. We obsereve a slightly positive linear relationship between these two variables. Detailed relationship will be studied in Section 3.

Next is the Current health expenditure. From Figure 3a, we see that it ranges from 0 to 12000, but the shape of the distribution is extremely skewed to the right. Thus we decided to perform a log transformation to stabilize the normal shape. Figure 3b is the histogram after



(a) Histogram of each countries' food production index

(b) Scatter plot of each countries' Food production index VS. Log of Mortality

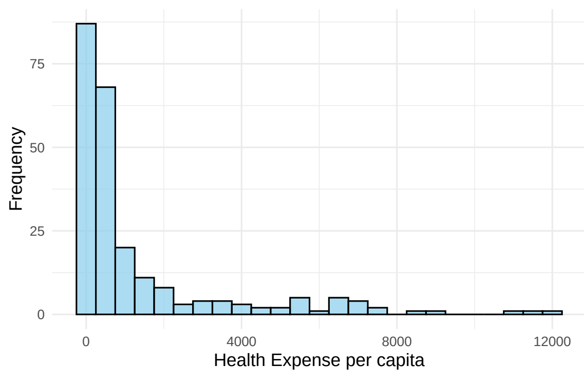
Figure 2: Data Analysis of Predictor Food Production Index

the log transformation, we see that it now ranges from 0 to 10 with a center at 6 and the shape a approximately normal now. Figure 3c is a scatter plot between Log of Mortality rate and Log of Current health Expenditure, with a best line of fit and standard error. We observe a significant negative linear relationship between these two variables. Detailed relationshape will be studied in Section 3.

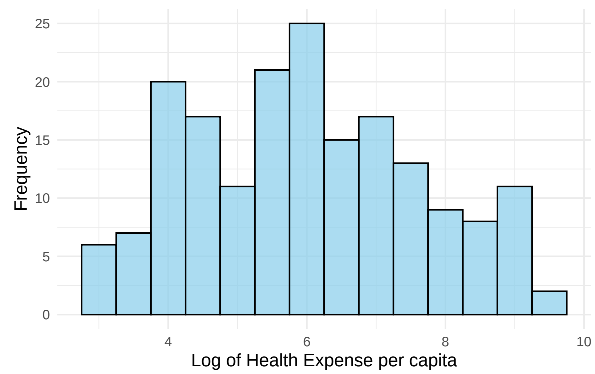
Finally is the DPT vaccine percentage. From Figure 4a, we see that it ranges from 30 to 100, but the shape of the distribution is skewed to the left, we will discuss this in Section 4. Here we do not have efficient tecnics to stablize the distribution. Figure 4b is a scatter plot between DPT vaccine percentage and Log of Mortality rate, with a best line of fit and standard error. We observe a significant negative linear relationship between these two variables. Detailed relationship will be studied in Section 3.

2.5 Missing Data and Time Inconsistancy

In our file, the varible Health Expendure is collect for year 2021 while the others is collected in year 2022. We done this is because there is n data avliable for year 2022 of this data. We believe that these data are recent and so the data collected in year 2021 could still do a good job associating data in 2022. Also there are a few data missing for some minor countries. We made the decision to drop them and continue our modeling. We will discuss further implications of these two in Section 4



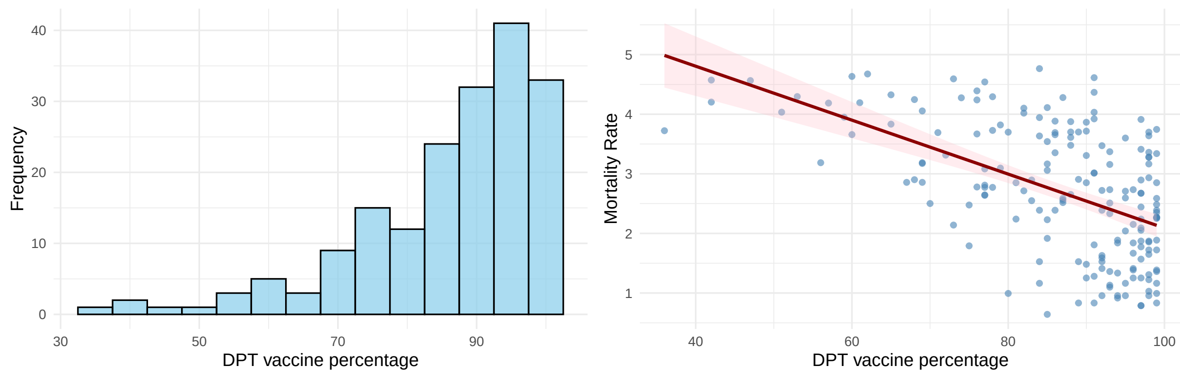
(a) Histogram of each countries' Health Expenditure Per Capita, Measured in US$. Before log transformation



(b) Histogram of each countries' Health Expenditure Per Capita, Measured in US$. After log transformation

(c) Scatter plot of each countries' Health Expenditure Per Capita, Measured in US$ VS. Log of Mortality

Figure 3: Data Analysis of Predictor Current Health Expenditure



(a) Histogram of each countries' DPT vaccine percentage

(b) Scatter plot of each countries' DPT Vaccine Percentage VS. Log of Mortality

Figure 4: Data Analysis of Predictor DPT Vaccine Percentage

3 Model

The goal of our modeling strategy is to investigate how the DDT vaccine coverage, food production index, and current health expenditure per capita (current US$) relate to the under-five mortality rate for each nation.

We aim to use this model to understand how the above mentioned three factors' impact on child mortality and identify opportunities for improving health outcomes, especially for high mortality rate nations. Background details and diagnostics are included in Appendix B.

3.1 Model set-up

Let y_i be the logrithm of under-five mortality rate for nation i. We define the following predictors:

x_{1i}: DDT vaccine coverage for nation i. x_{2i}: Food production index for nation i. x_{3i}: Logrithm of current health expenditure per capita (current US$) for nation i. The model is specified as:

$$
\begin{aligned}
y_i \mid \mu_i, \sigma &\sim \text{Normal}(\mu_i, \sigma) && (1)\\
u_i &= \alpha + \beta_1 x_{1i} + \beta_2 x_{2i} + \beta_3 x_{3i} && (2)\\
\alpha &\sim \text{Normal}(5,) && (3)\\
\beta_1 &\sim \text{Normal}(0, 2.5) && (4)\\
\beta_2 &\sim \text{Normal}(0, 2.5) && (5)\\
\beta_3 &\sim \text{Normal}(0, 2.5) && (6)\\
\sigma &\sim \text{Exponential}(1) && (7)
\end{aligned}
$$

We implement this model in R (R Core Team 2023) using the rstanarm package (Goodrich et al. 2022), employing its default priors for predictors and a distribution of Normal(_i,).

3.1.1 Model justification

We use a multivariate linear model to capture the relationship between the predictors and the response variable. This choice is justified by the linear trends observed in the data (see Section 2). The logarithmic transformation of the under-five mortality rate and current health expenditure per capita is applied to stabilize variance and linear relationships, ensuring model validity.

The Bayesian framework is employed due to its ability to incorporate prior knowledge, improve uncertainty quantification, and handle small sample sizes effectively.

4 Results

Our results are summarized in **?@tbl-modelresults**.

###Intercept: The intercept estimate of 6.643 represents the expected logarithm of the under-five mortality rate when all predictors are held constant at their reference or baseline values (e.g., average food production, average vaccine coverage, and average health expenditure). This serves as a baseline for interpreting the effects of the predictors.

###Food: Food Production Index: The coefficient for the food production index is 0.003, indicating a very slight positive relationship between food production and the under-five mortality rate. This naïvely suggests that reducing food production could also reduce mortality, which is counter-intuitive.

However, a closer examination of the confidence interval for this predictor shows that it includes 0. This implies that the relationship is not statistically significant, and food production is not strongly related to overall under-five mortality rates. This finding suggests that while food production is essential for societal well-being, its immediate impact on reducing child mortality might depend on other factors such as food access, distribution systems, and nutritional quality.

###Vaccine Coverage: The coefficient for vaccine coverage is -0.013, meaning that for every 1 percentage point increase in vaccine coverage, the logarithm of the under-five mortality rate decreases by 1.3%, holding other variables constant.

This highlights the critical role of vaccination programs in reducing child mortality. For example, increasing vaccine coverage by 10 percentage points could reduce the mortality rate by approximately 13%, emphasizing the importance of robust immunization initiatives.

###Health Expenditure (Log-Transformed): The coefficient for the log-transformed health expenditure is -0.529, indicating that a 1% increase in health expenditure per capita is associated with a 0.529 unit decrease in the log of the under-five mortality rate, holding all other predictors constant.

Term	Estimate	Std. Error	2.5% CI	97.5% CI
(Intercept)	6.643	0.363	6.047	7.222
Food	0.003	0.002	0.000	0.007
Vacinne	-0.013	0.003	-0.019	-0.008
Health_expense	-0.529	0.029	-0.578	-0.482

“‘

5 Discussion

5.1 First discussion point

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5.2 Second discussion point

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5.3 Third discussion point

5.4 Weaknesses and next steps

Weaknesses and next steps should also be included.

Appendix

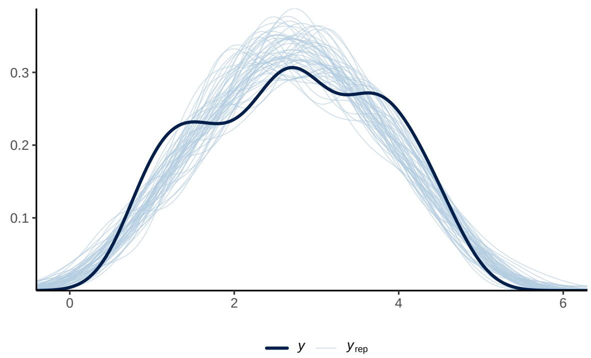
A Additional data details

B Model details

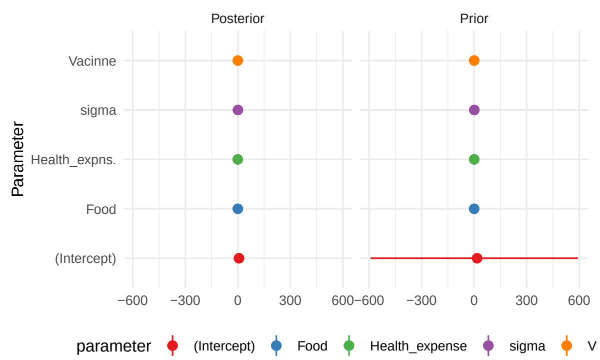
B.1 Posterior predictive check

In Figure 5a we implement a posterior predictive check. This shows...

In Figure 5b we compare the posterior with the prior. This shows...



(a) Posterior prediction check



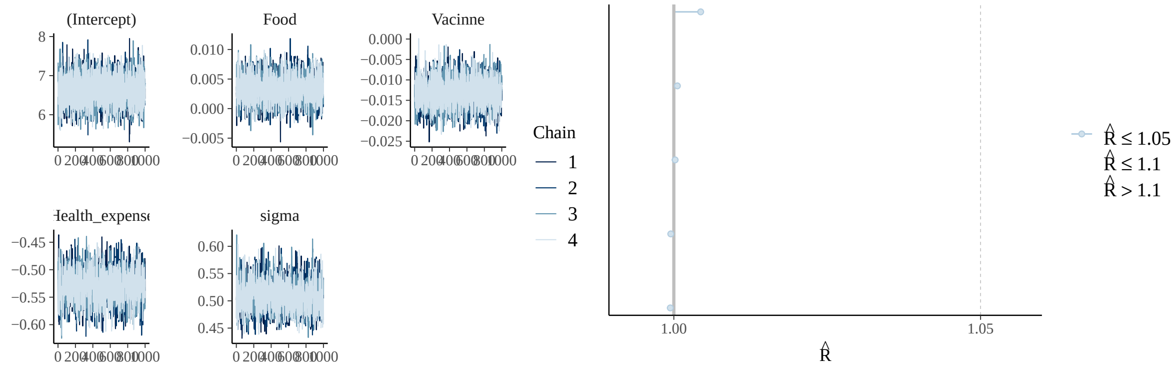
(b) Comparing the posterior with the prior

Figure 5: Examining how the model fits, and is affected by, the data

B.2 Diagnostics

Figure 6a is a trace plot. It shows... This suggests...

Figure 6b is a Rhat plot. It shows... This suggests...



(a) Trace plot

(b) Rhat plot

Figure 6: Checking the convergence of the MCMC algorithm

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