

Question 3 + 4

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Question 3 - See QMD for Code

(a) Import each dataset into memory as a separate data frame, keeping all countries as your sample.

```
plt.rcParams.update({'font.size': 14})

# Loading in the Data
Health_Data = pd.read_csv('Data/Health.csv', index_col=None)
Infant_Data = pd.read_csv("Data/Infant.csv", index_col=None)

# Replace .. with NA
Health_Data.replace("..", pd.NA, inplace=True)
Infant_Data.replace("..", pd.NA, inplace=True)

# Removing unnecessary columns
Health_Data = Health_Data.drop(columns=['Series Name', 'Series Code'])
Infant_Data = Infant_Data.drop(columns=['Series Name', 'Series Code'])

# Remove names in []
Health_Data.columns = Health_Data.columns.str.replace(r'\[.*\]', '', regex=True)
Infant_Data.columns = Infant_Data.columns.str.replace(r'\[.*\]', '', regex=True)

print(Infant_Data.head())
print(Health_Data.head())
```

	Country Name	Country Code	2000	2001	2002	2003	2004	2005	2006	\
0	Afghanistan	AFG	92	89.3	86.6	83.7	80.9	78	75.1	
1	Albania	ALB	24	22.9	21.6	20.4	19.1	17.8	16.5	
2	Algeria	DZA	35.6	34.3	33	31.6	30.3	29	27.8	
3	American Samoa	ASM	<NA>	<NA>	<NA>	<NA>	<NA>	<NA>	<NA>	

4	Andorra	AND	6.5	6.3	6	5.8	5.6	5.3	5.1
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	2007	...	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
0	72.3	...	56.2	54.6	53	51.5	50.1	48.8	47.4	46.1	44.8	<NA>
1	15.3	...	8.8	8.5	8.4	8.3	8.3	8.3	8.4	8.4	8.4	<NA>
2	26.6	...	22	21.7	21.4	21	20.6	20.1	19.7	19.2	18.7	<NA>
3	<NA>	...	<NA>	<NA>	<NA>	<NA>	<NA>	<NA>	<NA>	<NA>	<NA>	<NA>
4	4.9	...	3.5	3.4	3.2	3.1	3	2.9	2.8	2.7	2.6	<NA>

[5 rows x 26 columns]

	Country Name	Country Code	2000	2001	2002	\
0	Afghanistan	AFG	<NA>	<NA>	17.00758553	
1	Albania	ALB	65.1501236	73.78884125	78.99478149	
2	Algeria	DZA	62.11769485	67.33850098	66.94760132	
3	American Samoa	ASM	<NA>	<NA>	<NA>	
4	Andorra	AND	1287.00280762	1336.21142578	1486.171875	

	2003	2004	2005	2006	2007	\
0	17.81492424	21.42946434	25.10707283	28.91982269	32.71720505	
1	106.29218292	138.11340332	152.12762451	166.81382751	212.61096191	
2	76.23547363	93.02433014	101.30373383	117.43313599	151.77920532	
3	<NA>	<NA>	<NA>	<NA>	<NA>	
4	1772.71337891	1990.0748291	2214.64697266	2139.27539063	2489.43115234	

	...	2014	2015	2016	2017	\
0	...	60.18957901	60.05854034	61.48645782	66.90921783	
1	...	295.12359619	255.35635376	277.04321289	297.4619751	
2	...	361.15942383	292.275177	261.40023804	265.83843994	
3	...	<NA>	<NA>	<NA>	<NA>	
4	...	3089.84301758	2688.20629883	2755.44848633	2873.29614258	

	2018	2019	2020	2021	2022	2023
0	71.33430481	74.23410797	80.28805542	81.31976318	<NA>	<NA>
1	351.3012085	367.75839233	396.88024902	464.74285889	<NA>	<NA>
2	266.46469116	235.99041748	206.03512573	204.56661987	<NA>	<NA>
3	<NA>	<NA>	<NA>	<NA>	<NA>	<NA>
4	3164.38842773	3026.59741211	3269.29736328	3505.99145508	<NA>	<NA>

[5 rows x 26 columns]

(b) If data are not already stored in this way, please reshape data so that they consist of a single line of data for each country and year.

```
# Pivoting the Data into a long format
Health_Data_long = pd.melt(Health_Data,
    id_vars=['Country Name', 'Country Code'],
    var_name='Year',
    value_name='Heathcare Expenditure (USD)')
Infant_Data_long = pd.melt(Infant_Data,
    id_vars=['Country Name', 'Country Code'],
    var_name='Year',
    value_name='Infant Mortality Rates (per 1,000 live births)')
```

	Country Name	Country Code	Year	Heathcare Expenditure (USD)
0	Afghanistan	AFG	2000	<NA>
1	Albania	ALB	2000	65.1501236
2	Algeria	DZA	2000	62.11769485
3	American Samoa	ASM	2000	<NA>
4	Andorra	AND	2000	1287.00280762

	Country Name	Country Code	Year	Infant Mortality Rates (per 1,000 live births)
0	Afghanistan	AFG	2000	92
1	Albania	ALB	2000	24
2	Algeria	DZA	2000	35.6
3	American Samoa	ASM	2000	<NA>
4	Andorra	AND	2000	6.5

(c) Calculate the total number of countries observed in each data frame Calculate the total number of years observed in each data frame.

```
# Counts the number of unique contries
num_countries_FDI = Health_Data_long["Country Name"].nunique()

# Outputs the number of unique countries using an f string
print(f"Total number of unique countries in Health_Data: {num_countries_FDI}")

num_years_FDI = Health_Data_long["Year"].nunique() # Counts the number of unique years
print(f"Total number of unique years observed in Health_Data: {num_years_FDI}")
```

```

num_countries_GDP = Infant_Data_long["Country Name"].nunique()
print(f"Total number of unique countries in Infant_Data: {num_countries_GDP}")

num_years_GDP = Infant_Data_long["Year"].nunique()
print(f"Total number of unique years observed in Infant_Data: {num_years_GDP}")

```

```

Total number of unique countries in Health_Data: 217
Total number of unique years observed in Health_Data: 24
Total number of unique countries in Infant_Data: 217
Total number of unique years observed in Infant_Data: 24

```

(d) Calculate the number of observations for which data is missing

```

# Sums the number of missing values in each dataset
missing_values_Health = Health_Data_long.isna().sum().sum()
print(f"Total missing observations in Health_Data: {missing_values_Health}")

missing_values_Infant = Infant_Data_long.isna().sum().sum()
print(f"Total missing observations in Infant_Data: {missing_values_Infant}")

# Create a dataframe showing the number of missing values for each dataset
missing_values_table = pd.DataFrame({
    'Dataset': ['Health_Data', 'Infant_Data'],
    'Total Missing Observations': [missing_values_Health, missing_values_Infant]
})

```

```

Total missing observations in Health_Data: 1099
Total missing observations in Infant_Data: 700

```

(e) Join the two files by country and year so that you have single dataframe containing both variables. Explain clearly what type of join this is, and carefully check that the number of observations resulting from the join makes sense.

```

# Merge the data on Country Name, Country code and Year
merged_data = pd.merge(Health_Data_long, Infant_Data_long, on=['Country Name',
'Country Code', 'Year'])
print(merged_data.head())

# Print the number of rows in the DataFrame
num_rows = merged_data.shape[0]
print(f"Number of rows in the DataFrame: {num_rows}")

```

	Country Name	Country Code	Year	Healthcare Expenditure (USD)	\
0	Afghanistan	AFG	2000	<NA>	
1	Albania	ALB	2000	65.1501236	
2	Algeria	DZA	2000	62.11769485	
3	American Samoa	ASM	2000	<NA>	
4	Andorra	AND	2000	1287.00280762	

	Infant Mortality Rates (per 1,000 live births)
0	92
1	24
2	35.6
3	<NA>
4	6.5

Number of rows in the DataFrame: 5208

The join completed in the above code chunk is an inner join and only keeps rows that exist in both `Health_Data_long` and `Infant_Data_long`. If a country-year exists in one dataset but not the other, it will be dropped.

Question 4 - Investigating the Relationship Between Current Healthcare Expenditure per capita and Infant Mortality Rates from 2000 - 2022

Missing Data - Table 1

	Dataset	Total Missing Observations
0	Health_Data	1099
1	Infant_Data	700

Both datasets contained a considerable amount of missing data, illustrated in Table 1. Potentially due to countries not collecting the data or collecting the data at different year intervals. Missing data can have a large impact on data analysis if not handled properly and can lead to skewed or incorrect conclusions. The year 2023 contained no data; therefore, this column was dropped. To deal with the other missing data, I decided to drop all rows containing missing data, sometimes, this could result in a significant reduction of sample size; however, in this case, 1099 observations were removed (21.1% of the dataset) and only 27 countries were dropped, indicating this was an effective method to handling missing data as there were still 4109 observations. An alternative approach would've been mean, multiple or regression imputation if dropping rows with missing data caused a significant decrease in sample size.

Summary Statistics - Table 2

Variable	N	Mean	Median	SD	Min	Max
Healthcare Expenditure (USD)	4109.0	956.0	256.7	1685.7	4.0	12473.8
Infant Mortality Rates (per 1,000 live births)	4109.0	26.9	17.7	25.0	1.4	138.3

Table 2 displays the summary statistics for healthcare expenditure (USD) and infant mortality rates (per 1,000 live births) across 4109 observations, revealing significant differences between countries.

Healthcare expenditure per capita showed a mean of \$956.0 but a far lower median of \$256.7, indicating a negatively skewed distribution where few countries expenditure significantly more. The large standard deviation (\$1,685.7) and range (\$4.0–\$12,473.8) highlight large global and temporal differences in healthcare investment.

Infant mortality rates show similar variation, with a mean of 26.9 deaths per 1,000 live births and a median of 17.7. The high standard deviation (25.0) and range (1.4–138.3) suggest major differences in healthcare quality and access.

Overall, the data indicates global differences in healthcare funding and outcomes, suggesting that higher healthcare expenditure may be linked to lower infant mortality.

Distribution Analysis

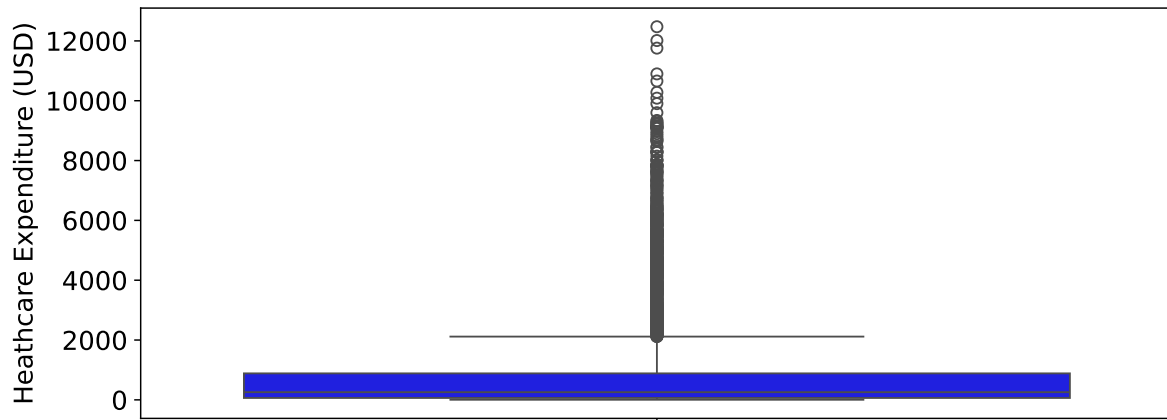


Figure 1: Box Plot of Healthcare expenditure Per Capita (USD)

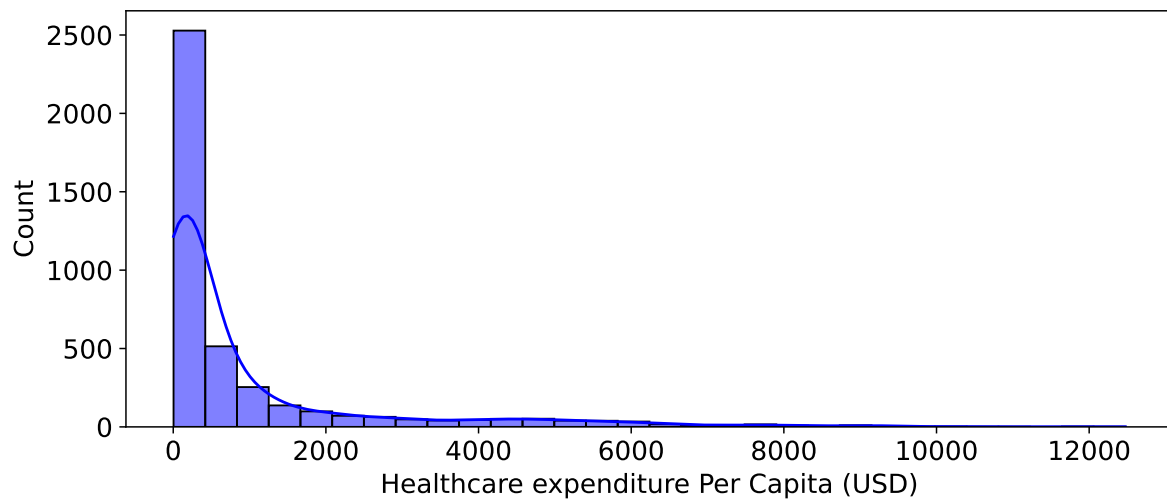


Figure 2: Histogram with Density of Healthcare expenditure Per Capita (USD)

Figures 1 and 2 show the distribution of healthcare expenditureing per capita (USD). Figure 1 shows that healthcare expenditure is highly negatively skewed, with many outliers at the upper end, supporting the analysis from the summary statistics. The median expenditure is positioned toward the lower end of the distribution, indicating that most countries expenditure relatively little, while a few spending significantly more. The whiskers of the box plot are short, suggesting that a large proportion of the data is concentrated within a lower range, while the numerous outliers highlight extreme expenditureing levels in some countries.

Figure 2 reiterates the negative skew of the data. Most countries have low healthcare expenditure, grouped toward the left of the axis, with just a handful having exceptionally high expenditures. The density curve (smooth blue line) shows the exponential drop in frequency

as expenditure increases, emphasising that high-spending countries are exceptions rather than the rule

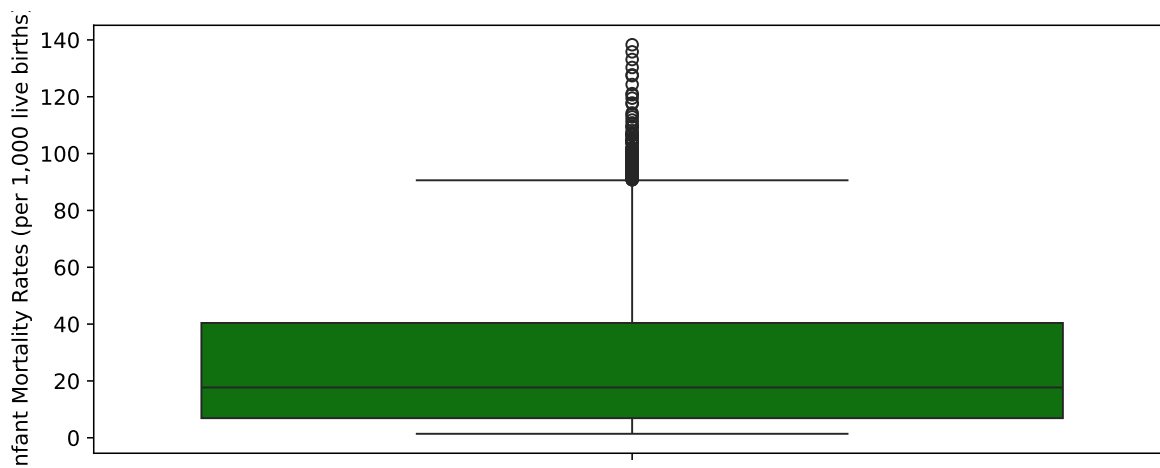


Figure 3: Box Plot of Infant Mortality Rate (per 1,000 live births)

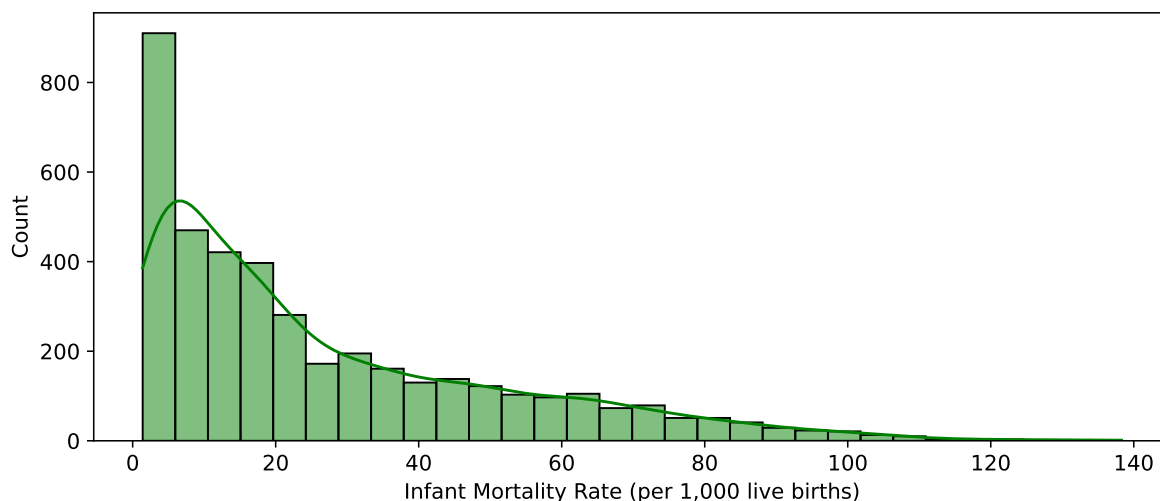


Figure 4: Histogram with Density of Infant Mortality Rate (per 1,000 live births)

The distribution of the infant mortality rate (per 1,000 live births) seen in Figures 3 and 4 is comparable to that of healthcare expenditure per capita (USD).

There are several outliers in Figure 3, with specific countries having abnormally high infant mortality rates. The data is still negatively skewed, as seen by the median being significantly lower than the upper quartile.

This is supported by Figure 4, which displays a dramatic fall in frequency as rates rise, with most values clustering below 40 deaths per 1,000 live births. While infant mortality is low in many nations, it is much higher in others, most likely because of infrastructural constraints, economic considerations, and healthcare discrepancies.

Due to the number of outliers within both variables, I decided to use the Interquartile Range (IQR) method to remove any outliers to ensure a more accurate and reliable regression analysis.

Outliers can skew the model fit, disproportionately influence regression coefficients, and inflate evaluation metrics such as RMSE. By applying the IQR method, I ensure that the data represents a more consistent trend, reducing the impact of extreme values and improving the model's ability to capture the true relationship between healthcare expenditure and infant mortality rates.

Correlation Analysis

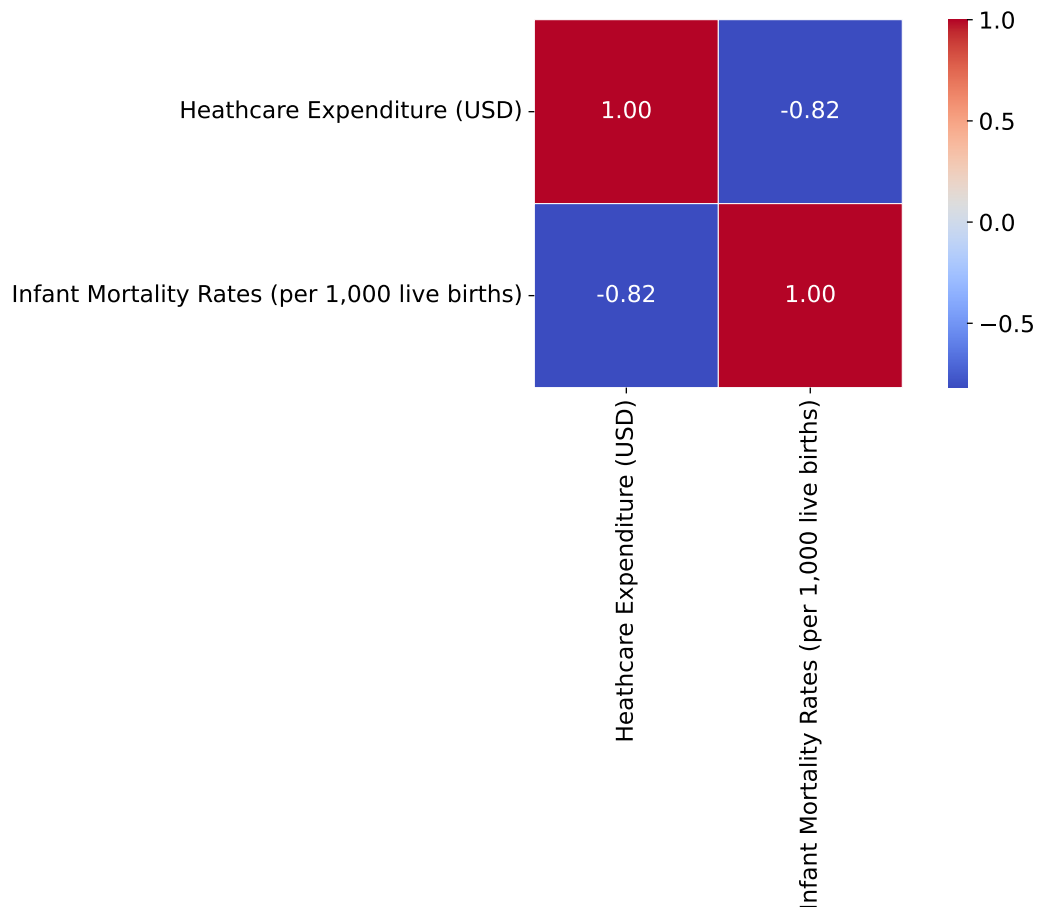


Figure 5: Spearman Rank Correlation Matrix of Healthcare Expenditure and Infant Mortality Rates

Figure 5 illustrates the relationship between healthcare expenditure and infant mortality rates. The correlation coefficient of -0.82 indicates a strong negative correlation, suggesting that as healthcare expenditure increases, infant mortality rates tend to decrease. This aligns with economic and public health expectations, where greater investment in healthcare typically leads to better medical infrastructure, improved maternal care, and reduced infant deaths. The

Spearman correlation is particularly useful here as it captures non-linear relationships, making it more robust to potential outliers compared to Pearson’s correlation. However, correlation does not imply causation, and additional factors such as healthcare efficiency, socioeconomic disparities, and government policies could influence this relationship.

Regression Analysis

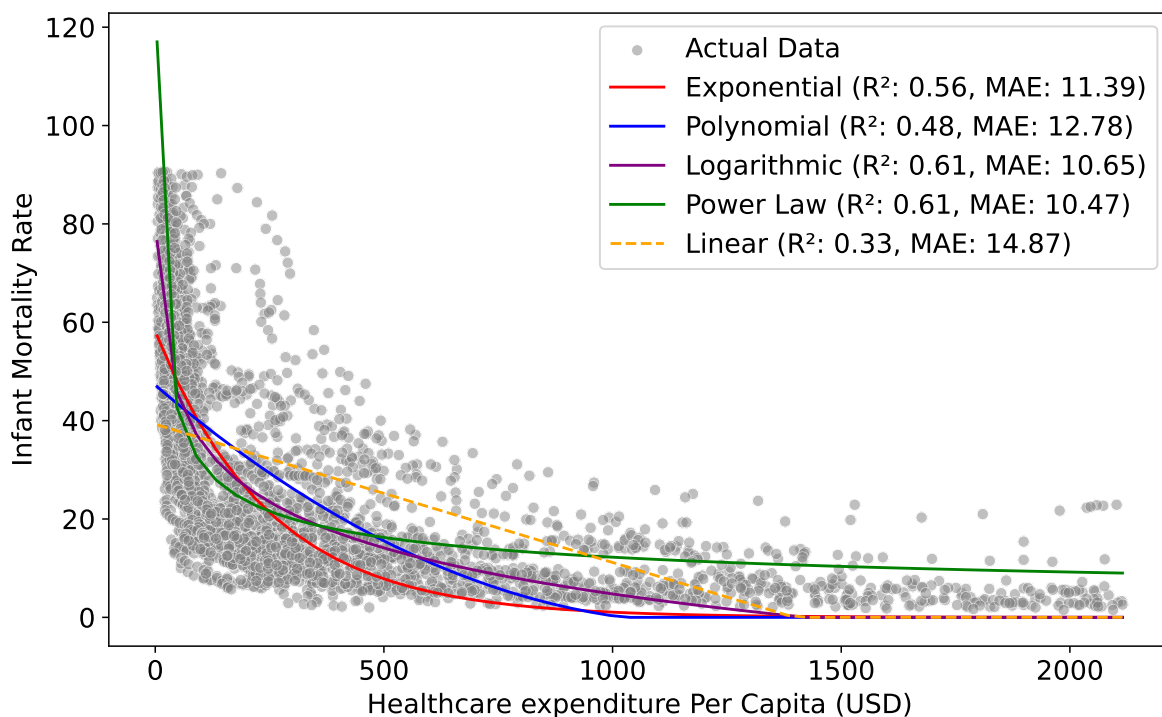


Figure 6: Comparison of Regression Models: Healthcare Spend vs Infant Mortality Rate

Figure 6 compares five regression models, exponential, polynomial, logarithmic, power law, and linear, in quantifying the relationship between healthcare expenditure per capita and infant mortality rates. The power law model achieves the best fit with an R^2 of 0.61, revealing that 61% of the variance in infant mortality rates is explained by healthcare expenditure per capita, and the lowest mean absolute error (MAE) of 10.47, supporting the strong inverse relationship shown in Figure 5. Exponential and logarithmic regression perform well ($R^2 = 0.61$ and 0.56 , respectively), capturing the steep initial decline before stabilizing at lower mortality levels.

Polynomial regression initially follows the trend but ultimately performs poorly, indicated by its lower R^2 of 0.48. The linear model performs worst, failing to capture the non-linearity of the data. All models are constrained to prevent infant mortality predictions below 0, ensuring a realistic representation. This analysis highlights that non-linear models, particularly power law and exponential regression, provide the most accurate representation of the data, reiterating the non-linearity of the relationship between healthcare expenditure per capita and infant mortality rates.

Regression Model Evaluation

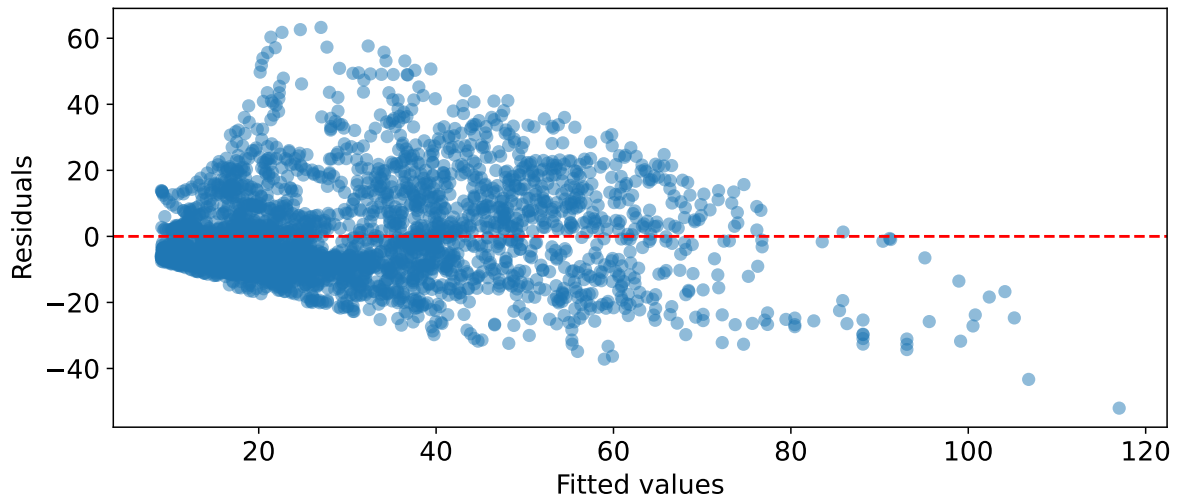


Figure 7: Residual Plot of Power Law Regression

The residual plot (Figure 7) for the power law regression model highlights some issues with the model's fit. The residuals display a noticeable pattern rather than being randomly scattered, suggesting heteroscedasticity—where the variance of residuals increases with fitted values. This indicates that the model performs well at lower levels of healthcare expenditure but struggles to maintain accuracy as expenditure increases. The presence of extreme residuals also suggests potential outliers influencing the model. To address these issues, applying a log transformation to the dependent variable or exploring alternative regression techniques, such as Generalized Least Squares (GLS), may help improve the model's fit.

Time Series Analysis

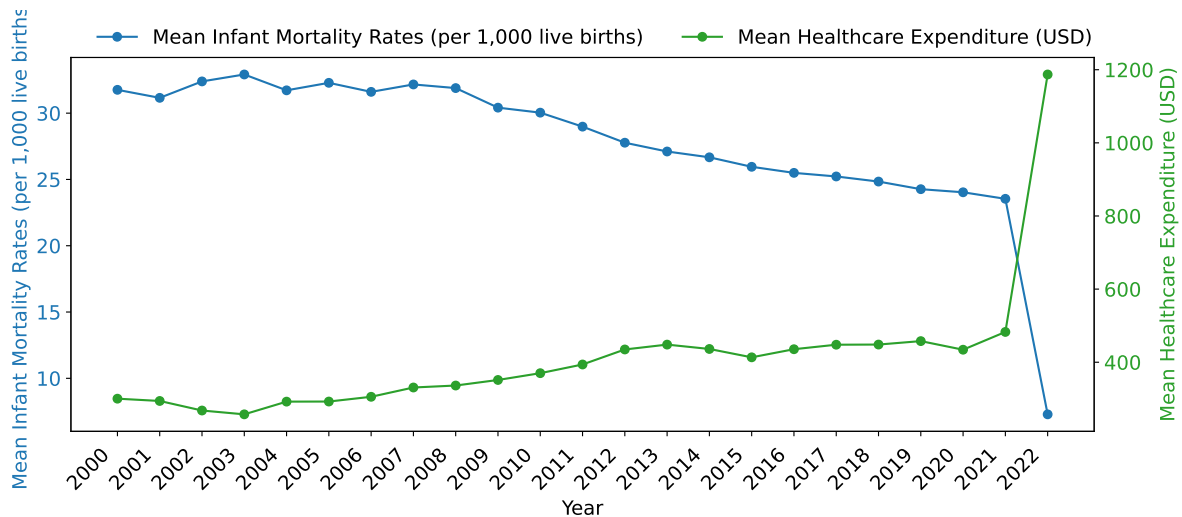


Figure 8: Time Series Analysis of Mean Infant Mortality Rates and Healthcare Expenditure

Figure 8 illustrates the negative association between mean infant mortality rates (IMR) and mean healthcare expenditure (USD) from 2000 to 2022. The trend indicates a continual drop in IMR, reflecting improvements in healthcare, economic development, and medical advances. Meanwhile, healthcare expenditure has steadily climbed, indicating greater investment in health infrastructure and services.

A noteworthy anomaly arises in 2022 when healthcare expenditures significantly increase and infant death rates significantly decrease. This large shift may be due to pandemic-related expenditure, emergency health interventions, or data errors. The high rise in expenditure may signal a significant policy shift, but further research is needed to assess the long-term consequences.

Overall, Figure 8 reinforces the strong negative correlation between healthcare expenditure and infant mortality rates illustrated by Figures 5 and 6. However, the presence of diminishing returns suggests that beyond a certain threshold, additional expenditure alone may not yield proportional improvements, emphasizing the need for efficient resource allocation and targeted healthcare policies to maximize impact.

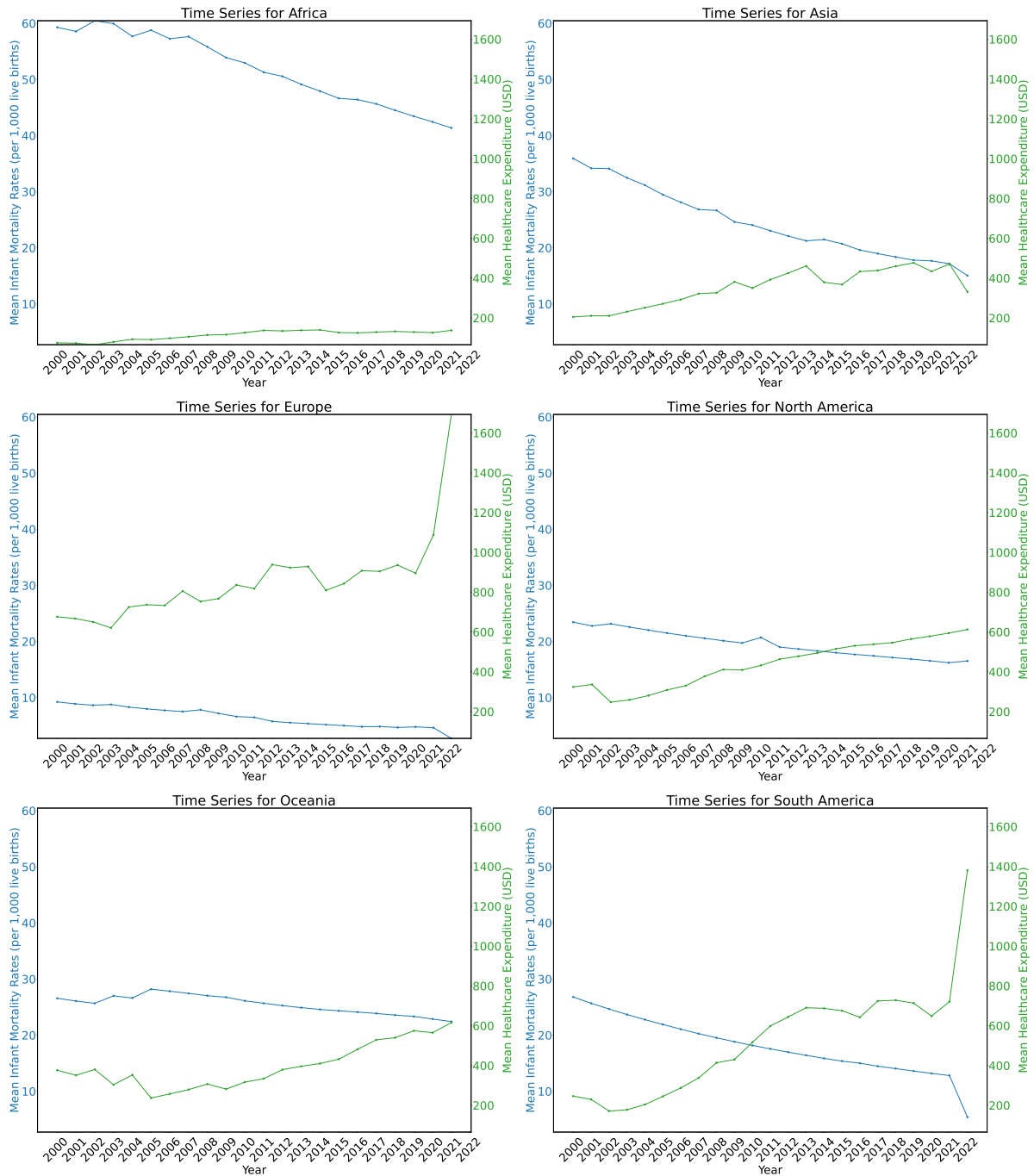


Figure 9: Time Series Analysis of Mean Infant Mortality Rates and Healthcare Expenditure By Continent

Figure 9 shows continent-specific trends in IMR and mean healthcare expenditure (USD) from 2000 to 2022. The constant negative relationship across each location suggests an association between increasing healthcare investment and reduced infant mortality.

Africa and Asia have had considerable drops in IMR, indicating significant improvements in healthcare despite relatively little investment. Europe and North America, with larger beginning expenditures, experienced lower IMR decreases, indicating declining returns on investment. South America and Oceania follow similar trends but have different purchasing preferences.

Healthcare expenditure rose significantly in 2022 in North and South America, most likely because of pandemic-related measures. This substantial rise in expenditure corresponds to a transient acceleration in IMR decreases, implying short-term healthcare gains.

Overall, Figure 9 highlights regional differences in healthcare availability and efficiency. While investment is critical to lowering infant mortality, the impact of expenditure varies by location.

Conclusion

This analysis confirms a strong non-linear negative relationship between healthcare expenditure and infant mortality rates across global regions. Countries with higher healthcare investment generally experience lower infant mortality, though the impact varies based on economic and healthcare infrastructure factors.

The non-linear nature of this relationship indicates diminishing returns, where initial increases in spending lead to substantial improvements, but further investments yield smaller reductions in infant mortality. Logarithmic and time-series analyses further reinforce this pattern, highlighting long-term declines in infant mortality alongside growing healthcare expenditure.

Regional disparities remain significant, with high-income regions investing more per capita while achieving lower mortality rates, whereas lower-income regions show greater relative improvements despite lower absolute expenditure. The 2022 anomaly suggests short-term shifts in healthcare spending and outcomes, likely due to pandemic-driven policies.

While healthcare expenditure is a crucial driver of infant mortality rates, efficient allocation, accessibility, and policy effectiveness remain key determinants of long-term health improvements worldwide.

Link to GitHub Repository = <https://github.com/JoshLG18/DSE-Assignment1>