Analyzing the Relationship Between GDP and Life Expectancy Over Time

Jack Yeung[a,1]

[a]*Indiana University*

1. Introduction

This report explores the relationships between GDP per capita and life expectancy across different countries and continents over time. Specifically, it examines whether the increase in life expectancy since World War II can largely be attributed to economic growth. Various factors influencing life expectancy and their interrelationships will be analyzed throughout this study.

2. Abstract

Gapminder [1], a Swedish organization, has compiled a dataset spanning from 1952 to 2007, containing estimates of Gross Domestic Product (GDP), life expectancy, population, and other key descriptive statistics for 142 unique countries across five continents. This dataset will be used to investigate the impact of various factors on life expectancy through statistical methods, including linear regression and LOESS regression, to uncover meaningful patterns and relationships.

3. General Statistics

Before examining the relationships between various factors and life expectancy, an initial exploration of individual features will be conducted to develop intuition that may help lead our analysis. Looking at Life Expectancy and Gross Domestic Product(GDP) Per Capita individually may improve the understanding of the relationships between these two features.

3.1. Life Expectancy

We note the five highest highest countries and their respected continent averaged for each year.

Table 1. Mean Life Expectancy

Continent	Country	Life Expectation
Europe	Iceland	76.51
Europe	Sweden	76.17
Europe	Norway	75.84
Europe	Netherlands	75.64
Europe	Switzerland	75.56

Note: The table contains the life expectancy averaging over the entire time region

Interestingly, each of these countries are located in close proximity within the Scandinavian region. However, 55 years is an extended period of time for which many global events arise. Is this because these countries already had high life expectancy or was it because of a an increase? The mean life expectancy is insufficient to answer such questions. Therefore, a basic analysis of growth rate is important.

Table 2. Highest Growth in life expectancy

Continent	Country	Growth(%)
Asia	Oman	101.3
Africa	Gambia	98.2
Asia	Yemen	92.6
Asia	Indonesia	88.5
Asia	Vietnam	83.7

Note: This table shows the growth rate o

We observe that 4 out of 5 countries are located in Asia with the highest country of Oman showing a 101% growth rate in Life expectancy. Again, a majority of countries within the table are from the same continent. How does continent affect Life Expectancy?

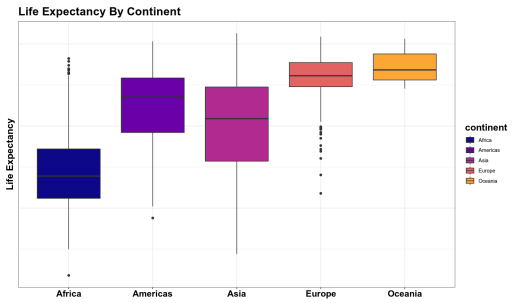


Figure 1. Life Expectancy for Each Continent

The histogram above illustrates varying life expectancy patterns across continents, with Oceania and Europe having the highest median life expectancy, while Africa has the lowest. Africa and Asia show the largest spread of of Life Expectancy among differing countries.

The disparities in life expectancy across continents suggest that various socioeconomic factors may be influencing health outcomes. One such critical factor is GDP per capita, which provides insight into a country's economic wealth and its potential impact on life expectancy

3.2. GDP Per Capita

The countries with the highest GDP per capita averaged per year are

Table 3. GDP Per Capita

Continent	Country	GDP(Per Capita)
Asia	Kuwait	65,332
Europe	Switzerland	27,074
Europe	Norway	26,747
Americas	United States	26,747
Americas	Canada	22410

Note: The table contains the GDP per capita averaged over the entire time region

Unlike life expectancy, the countries with the highest average GDP per capita are not concentrated within a single continent. The table highlights a significant gap between the top two countries, with Kuwait having more than double the GDP per capita of Switzerland. This substantial wealth can be attributed to Kuwait's abundant oil reserves, other natural resources, and a relatively small population. To further analyze the distribution of GDP per capita across different countries, a density estimate will provide deeper insight into how wealth, as measured by GDP per capita, is spread globally.

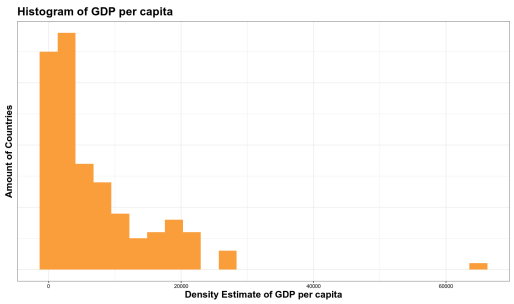


Figure 2. Distribution of Wealth

This figure gives evidence to a distribution similar to a logistic distribution a trend that also appears when plotting income of individuals. This pattern suggests that a majority of countries have lower wealth with only a select few countries holding a majority of these resources. Kuwait can be also be observed as the only country with GDP per Capita above 60,000.

4. GDP Trends in Life Expectancy in 2007

Insights gained from analyzing individual features guide our interpretation of relationships among these variables. To achieve this, we will apply different statistical models to estimate the relationship.

4.1. Transformation

Specifically, Figure 2 indicates the necessity of applying a log transformation to GDP per capita to achieve a more linear representation of the data. In Figure 3, we observe the effect of this transformation, where a linear regression is applied both to the raw GDP per capita and to its log-transformed counterpart in a scatter plot with life expectancy. The transformation enhances interpretability, making the relationship between the variables clearer.

4.2. Model Selection

Additionally, to enhance the flexibility of our linear regression, we will incorporate a modification using non-parametric techniques. By applying LOESS regression, we can fit localized linear models to different sections of the data, allowing for a more adaptive and accurate representation of trends.

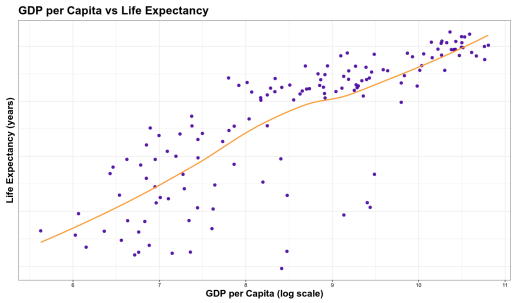


Figure 4. Loess Regression applied to log transformed data

Loess, seems to fit the trend of GDP and Life expectancy a bit better. There are some notable deviations from the model prediction particularly within countries who have high GDP and low life expectancy. This model may not have the complexity to handle such data.

4.3. Continental Differences

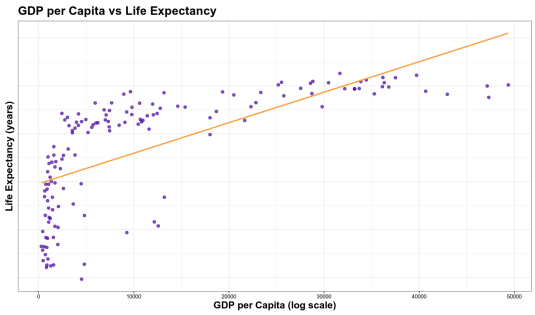
Lets examine this model on each of the continents to help understand if this is the root cause of deviation from the loess model. Within 5 We observe that Asia, Americas, and Europe seem to be better estimated using a linear model, with each country being explained by small shifts in the trend Africa on the other hand, shows a weaker correlation between log gdp and life expectancy. The trend line does not fit this data as well.

Important Note

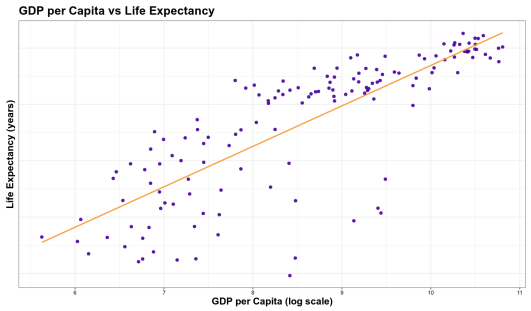
Oceania was excluded from this and some other plots due to its small sample size. With only two countries, analyzing GDP and life expectancy offered limited meaningful insights.

4.4. All years

The relationships can also be analyzed across all years. The plot below presents a linear model fitted to the entire dataset, revealing a stronger correlation between GDP per capita and life expectancy over time.



(a) Linear Regression Before Log Transformation



(b) Linear Regression After Log Transformation

Figure 3. Log Transformation

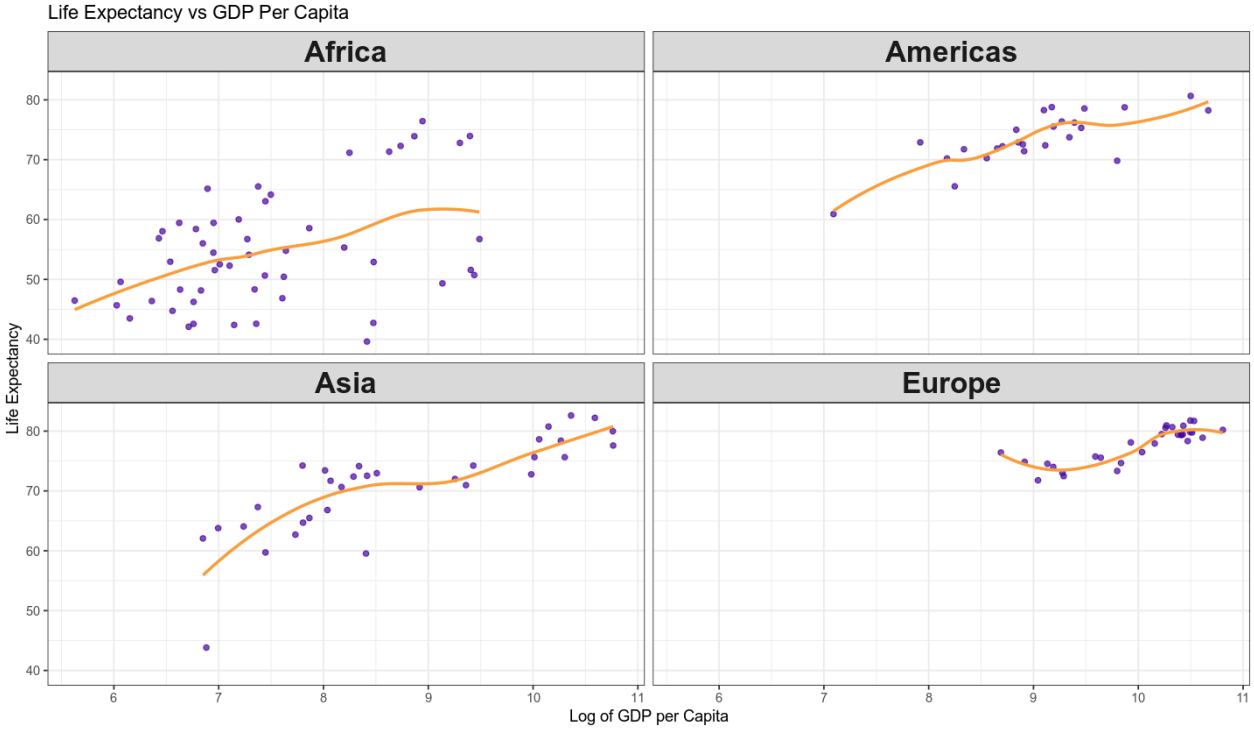


Figure 5. Loess Regression applied to Each Continent

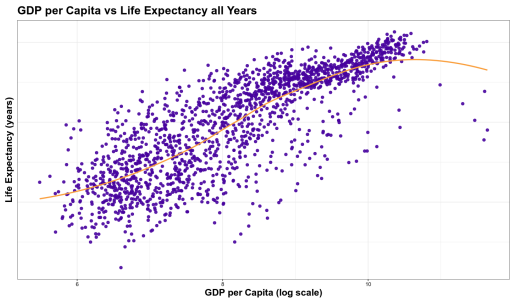


Figure 6. Loess Regression applied to all years

5. Temporal Trends in Life Expectancy

Figure 6 gives evidence to a temporal effect on life expectancy. To further understand the variance in life expectancy, particularly in Africa, it is essential to consider time as well. We will focus on the effect of time alone on life expectancy in the following sections.

5.1. Global Trends

The graph below presents the average life expectancy weighted by population over the year

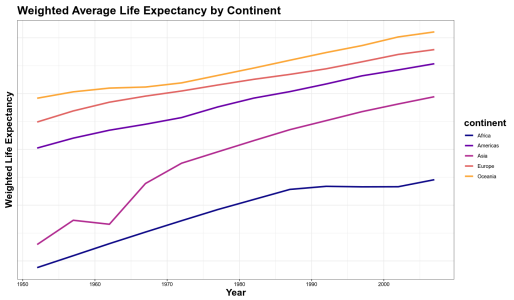


Figure 7. Weighted Life Expectancy for each continent over the years

Notably, the weighted life expectancy appears to increase at similar rates across all continents, suggesting that as global development progresses, so does life expectancy. However, Oceania and Europe exhibit higher initial levels in 1950, which may be attributed to early advancements in economic and healthcare development. To gain a more detailed perspective on these trends, rather than using a weighted average, all individual countries will be plotted.

5.2. Country Trends

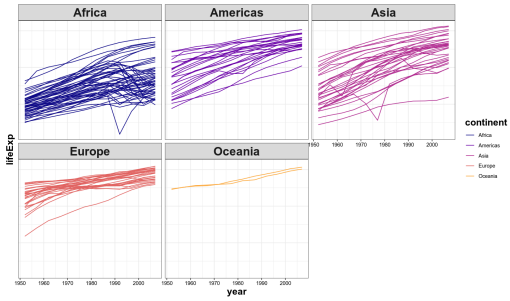


Figure 8. yearly trends plotted for each country in each continent

This visualization highlights the variance in life expectancy among Across different countries within each continent, the patterns generally follow a linear trend in growth of life expectancy but exhibit some slowdown in later years. However, some exceptions stand out, such as a country in Asia with a significantly lower trend line compared to others, as well as several countries in Africa. The patterns observed in Africa further reinforce the findings from Figure 8, highlighting distinct deviations specifically in 1990 that warrant closer examination.

5.3. High Variation in Africa

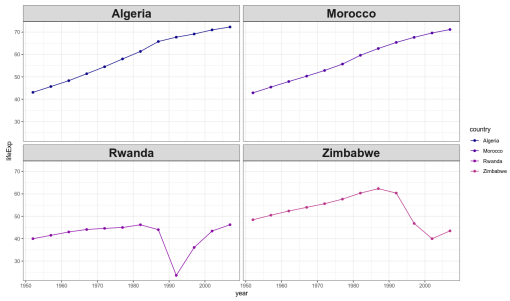


Figure 9. yearly life expectancy trends plotted for Algeria, Morocco, Rwanda, Zimbabwe

To further investigate these trends, specific countries have been selected for closer examination. Algeria, Morocco, Rwanda, and Zimbabwe illustrate some of the key variations observed. Rwanda and Zimbabwe experienced significant declines in life expectancy at the beginning of the 1990s, whereas Algeria and Morocco demonstrate steady growth in life expectancy over time. These observations can likely be attributed to historical events such as the Rwandan Civil War, the Second Congo War, the Liberian Civil War, and the Angolan Civil War[2].

6. Interaction Models

Does GDP alone impact life expectancy? What if both GDP per capita and time are considered together in ana-

lyzing their impact on life expectancy? Are there interactions that may be overlooked in the bivariate representations? To answer these questions, a three-dimensional scatter plot with a fitted linear plane is examined. This is achieved by extending the linear regression model to three dimensions.

6.1. Estimating Linear Relationships by GDP and Time

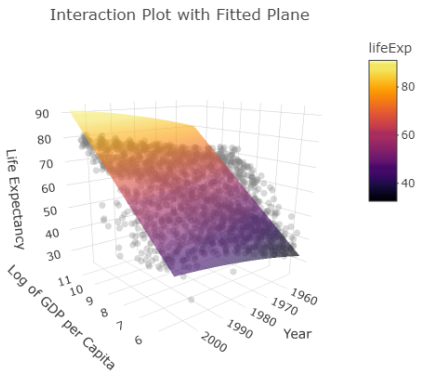


Figure 10. yearly trends plotted for each country in each continent

The scatter plot illustrates how the fitted linear plane is influenced by both year and log-transformed GDP per capita. The results indicate that countries in later years and those with higher GDP per capita generally exhibit increased life expectancy. Understandably, this graph makes some extended assumptions about the data. We can also utilize a loess regression to provide additional evidence of these relationships. Plotted below is a a contour graph representing this data.

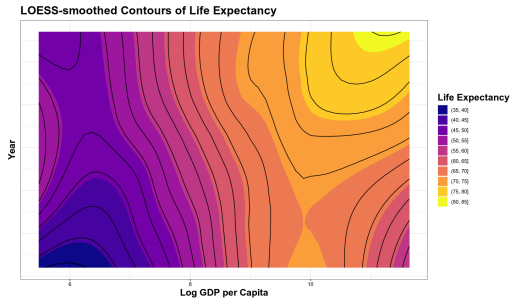


Figure 11. yearly trends plotted for each country in each continent

The contour shows us some nuance in the relationships among the three variables that the linear regression model could not. There appears to be some countries in the 1950s with a relatively high gdp per Capita yet with low life expectancy. This could explain one of the outlier points in 5.

6.2. Country Analysis

To further explore these interactions, continent-specific interaction plots are analyzed to examine how the relationship between log-transformed GDP per capita and life expectancy evolves over time.

These visualizations reveal distinct trends across continents. In Europe, countries demonstrate an overall increase in GDP per capita, while the relationship between GDP and life expectancy weakens over time. Asia, on the other hand, does not show a consistent increase in GDP per capita but does exhibit a general rise in life expectancy. The Americas display a "converging" effect, where the relationship between GDP and life expectancy weakens as life expectancy improves. Africa shows a steady increase in life expectancy, with GDP per capita playing an increasingly important role until 2002, after which the relationship appears to stabilize.

7. Conclusion

7.1. Concluding Remarks

Through the exploration of GDP per capita, time, and life expectancy, several key correlations have been identified. Most notably, there are strong positive relationships between log-transformed GDP per capita and life expectancy, as well as between time and life expectancy. These findings suggest that economic growth and overall global development play a significant role in increasing life expectancy over time.

7.2. Future Directions

As discussed in Section 4.2, the true relationships between these variables may be more complex than what a linear model can fully capture. Deviations from the expected trends, such as the case of Rwanda in Figure 9, highlight the impact of historical events like genocides in the 1990s. Global disruptions of this nature introduce non-linear patterns that a simple linear model may fail to account for. Future work could explore more sophisticated modeling approaches, such as machine learning models, to better capture these complexities.

References

[1] Gapminder, *Gapminder dataset*. [Online]. Available: https://www.gapminder.org/.

[2] Wikapedia. [Online]. Available: https://en.wikipedia.org/wiki/List_of_conflicts_in_Africa.

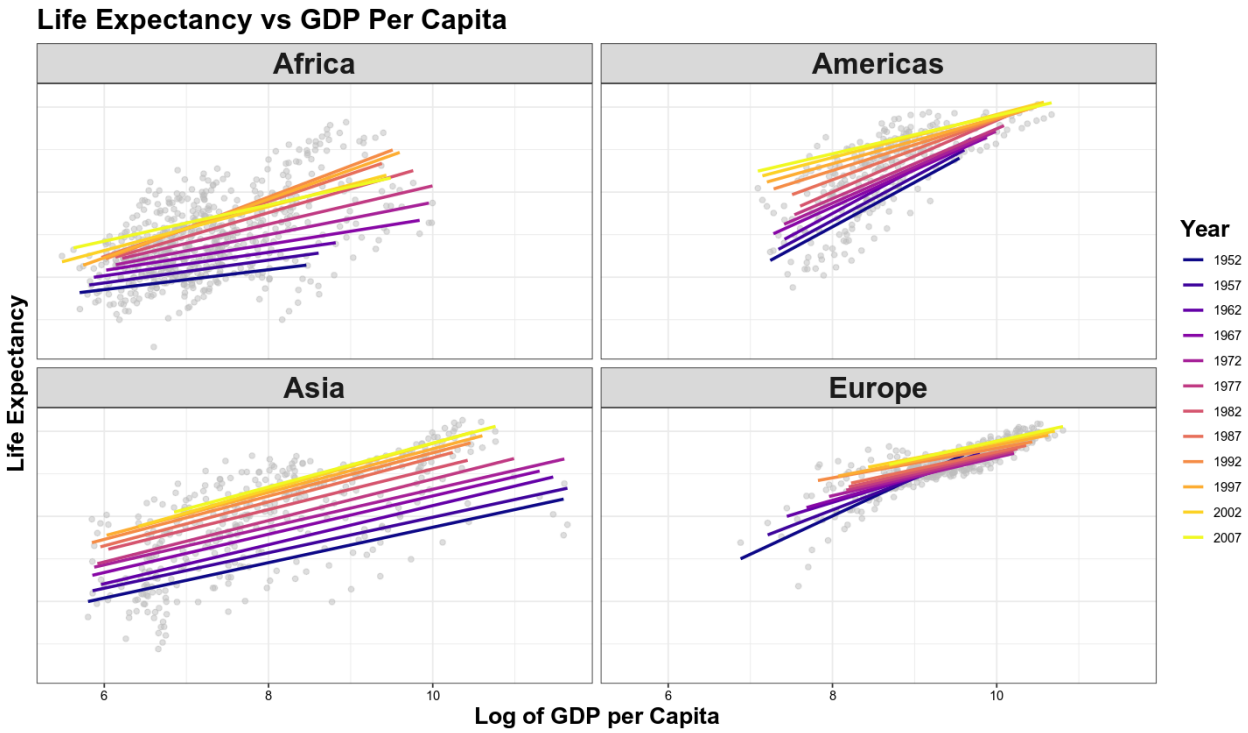


Figure 12. Relationship between GDP and life expectancy over the years