Life Expectancy at Birth and its Correlation with Gross Domestic Product

A Case Study Involving Six Nations

by Michelle A. Caler

Introduction

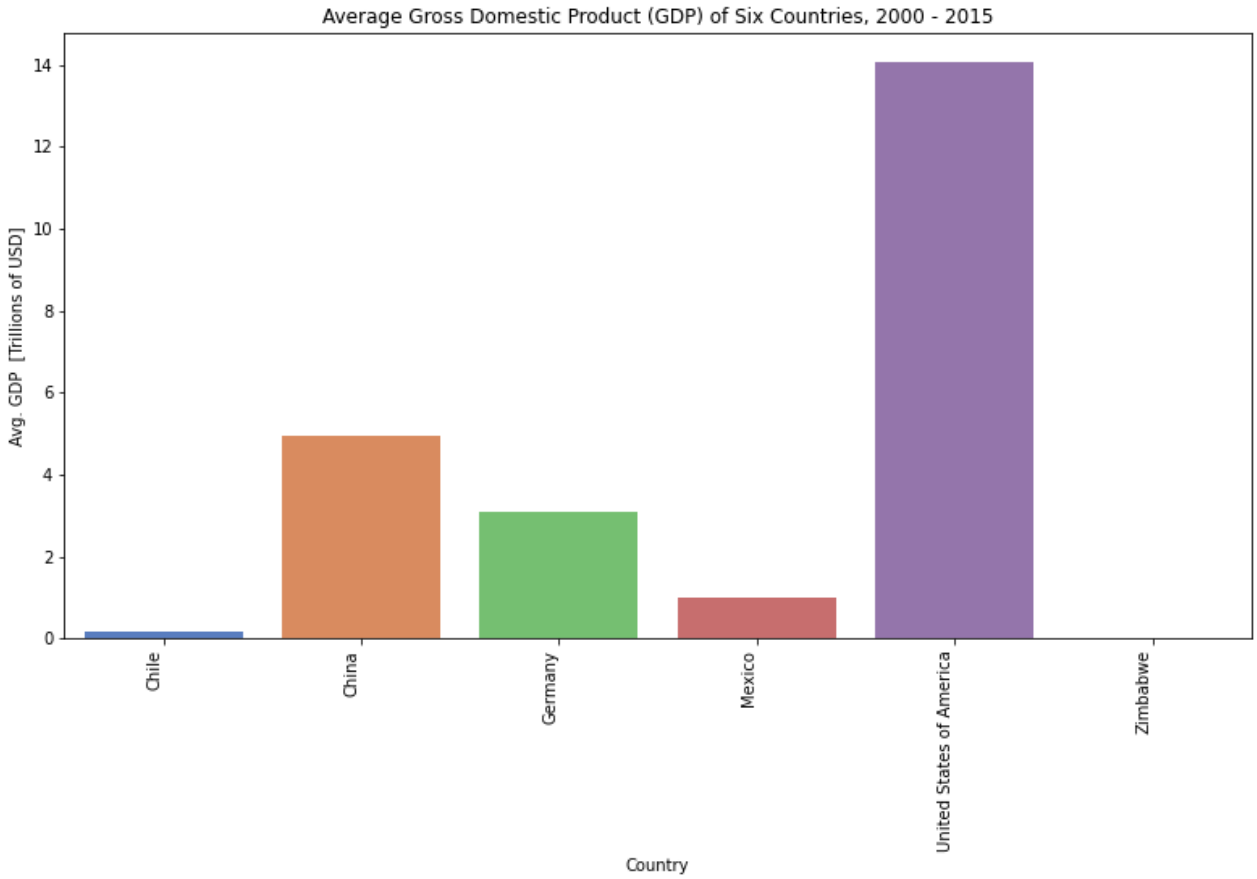
As a general rule, no matter where they reside on the Earth people want to live long, happy lives. The country in which a person was born, and the economic conditions they grew up in and reside in, influence a person's life expectancy. In this particular project, I looked specifically at life expectancy at birth, which is defined by the OECD as " how long, on average, a newborn person can expect to live if current death rates do not change[1]". The OECD also notes, "Gains in life expectancy at birth can be attributed to a number of factors, including rising living standards, improved lifestyle and better education, as well as greater access to quality health services.[1]" There are a number of different reasons why access to quality health services in a country may increase; undoubtedly, one of those reasons is that a country simply spends more on health services than it has previously. One possible marker for how much money a country has to spend on health services, among other things, is its gross domestic product, or GDP. As defined by Investopedia, a country's GDP is "the monetary value of all the finished goods and services produced within its borders by the country's citizens and foreigners[2]." It is calculated by adding together money spent on personal consumption, private investment, government spending, and the difference between the country's imports and its exports[2]. If we consider the specific case of health services, spending on such services can come from the private sector, the government sector, or both. It is also possible that an increase in a country's GDP results in an overall increase in living standards for its citizens, which also has a positive effect on life expectancy at birth. Thus, one might expect that gains in GDP could result in gains in life expectancy at birth.

In this article, I will be investigating the following, perhaps naïve, hypothesis: The higher a country's GDP, the higher its life expectancy at birth. In other words, GDP and life expectancy at birth are positively correlated. I'll investigate this not only in absolute terms—i.e., the hypothesis that the higher the monetary value of a country's GDP, the higher its life expectancy at birth—but also in relative terms, looking at trends in a particular country's GDP and its life expectancy at birth independent of other nations. Since I was provided with GDP and life expectancy at birth data for six nations—the United States of America, Mexico, Chile, Germany, Zimbabwe, and China—I will be concentrating my analysis on these particular nations. Represented in this list of nations is the country with the largest annual GDP (the United States), the world's second-largest economy (China), one of the largest economies in South America (Chile), the largest economy in Europe (Germany), and one of Africa's emerging economies (Zimbabwe). It will be interesting to compare the life expectancies at birth of these six nations and see how, if at all, it correlates with GDP. I should note that the data I have are historical, ranging from the year 2000 to the year 2015. So while I cannot look at recent trends of life expectancy at birth and GDP, I can look at it as of about 6 years ago. Perhaps trends have changed since then; perhaps they haven't. But nonetheless, it will be interesting to gain that historical perspective.

Average GDP and Average Life Expectancy at Birth

One of the first things you may want to know about 15 years of GDP and life expectancy at birth data is, “What is the average GDP of each nation?” followed shortly by, “What is the average life expectancy at birth of each nation?” (From here on in, I’ll frequently call life expectancy at birth “life expectancy,” since by now we all know what I am talking about. But occasionally I will type the full phrase out just to remind you.) This allows for a very rough comparison of GDP and life expectancy numbers between nations, but in my mind it’s not a very helpful statistic because of how much a country’s GDP is likely to change over a decade and a half. (Think about getting your average height between the ages of 1 and 15: how representative of your height during that timeframe do you think that average will be?) Getting those average values is at least a starting point for my investigation, so I’ve compiled them into a nice, visual form to make comparisons easier.

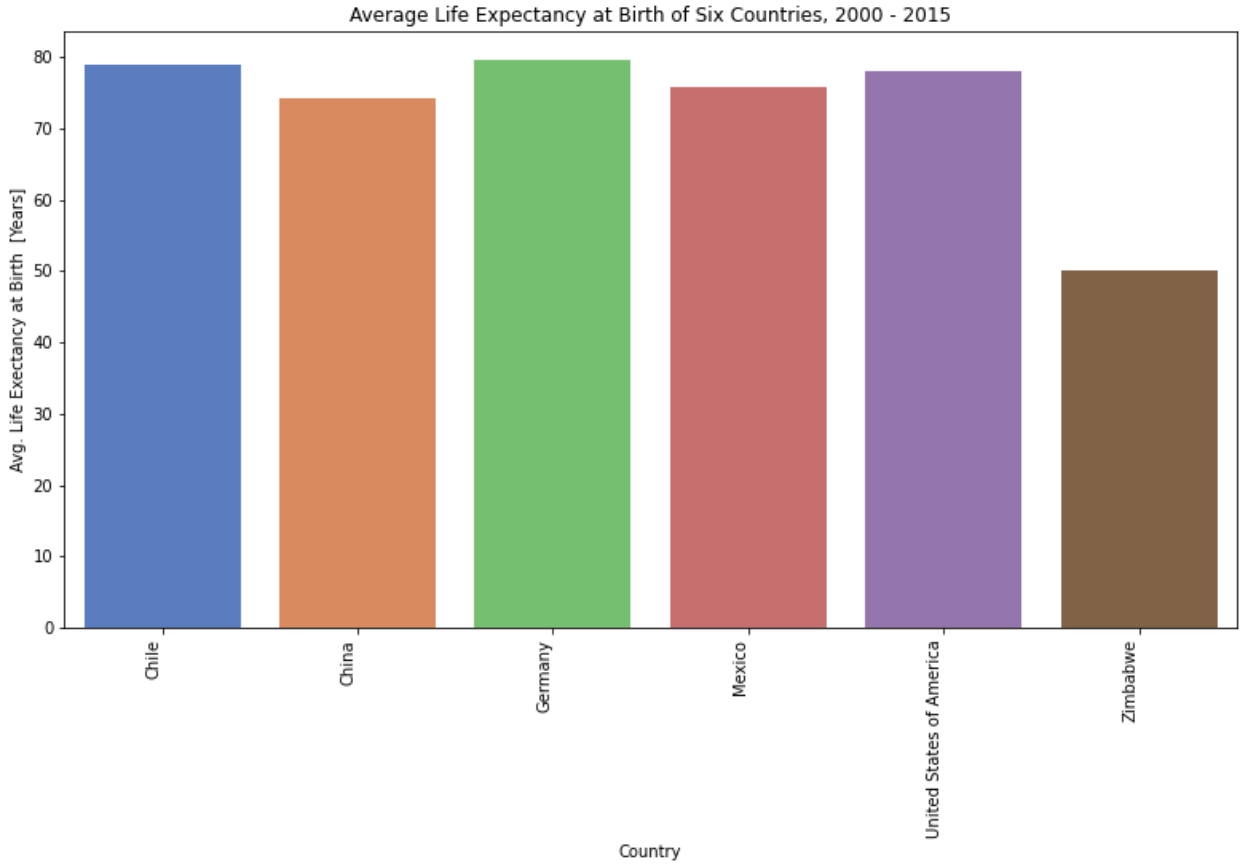
First, let’s look at average GDP. I should note that the GDP data I was provided with appear to be GDP per year, so I’ll be showing you the average yearly GDP over the 15-year period.



Note that these averages are in trillions of U.S. dollars (and, by my best estimate, 2018 U.S. dollars at that). This is important because the average GDP of Zimbabwe doesn’t even show up on this bar plot! Its average GDP over the 15-year time interval was 9.06 *billion* U.S. dollars (USD),

or a factor of 1,000 smaller than the average GDP of the United States (give or take a little bit). We can also see that Chile's GDP just barely registers on the plot; its average GDP was 170 billion USD, which corresponds to 0.17 trillion USD on the scale of the above plot. Clearly, there's a huge disparity in average annual GDP between large economies like the U.S. and emerging economies like Zimbabwe. But while this figure can give an indication of which nations have, overall, a high annual GDP and which have low ones, it glosses over a lot of important details. For example, China has become one of the dominant players in the world economy over the past 20 or so years, so taking an average of 15 years of GDP data probably doesn't give a robust picture of what its GDP has been like over that time. And from some brief research I did, the 15-year average for Zimbabwe glosses over the economic crisis of the early 2000s as well as the change in monetary policy in 2009 which led to a dramatic recovery of GDP. So while average GDP is a simple statistic to calculate, it smooths over important details which could impact my investigation into the correlation between GDP and life expectancy.

Speaking of life expectancy, let's have a look at the average life expectancy at birth of these six nations. Fortunately, we might expect all the average life expectancies to have roughly the same scale, as modern life expectancies don't tend to get much lower than 30 years and tend to top out at about 85 or so years. Note that unlike GDP, there does seem to be a maximum human lifespan (it's about 120 years or so currently, give or take a little bit), so that does set an upper limit on what average life expectancy can be. Well, without further ado, let's see that bar graph of average life expectancy at birth:



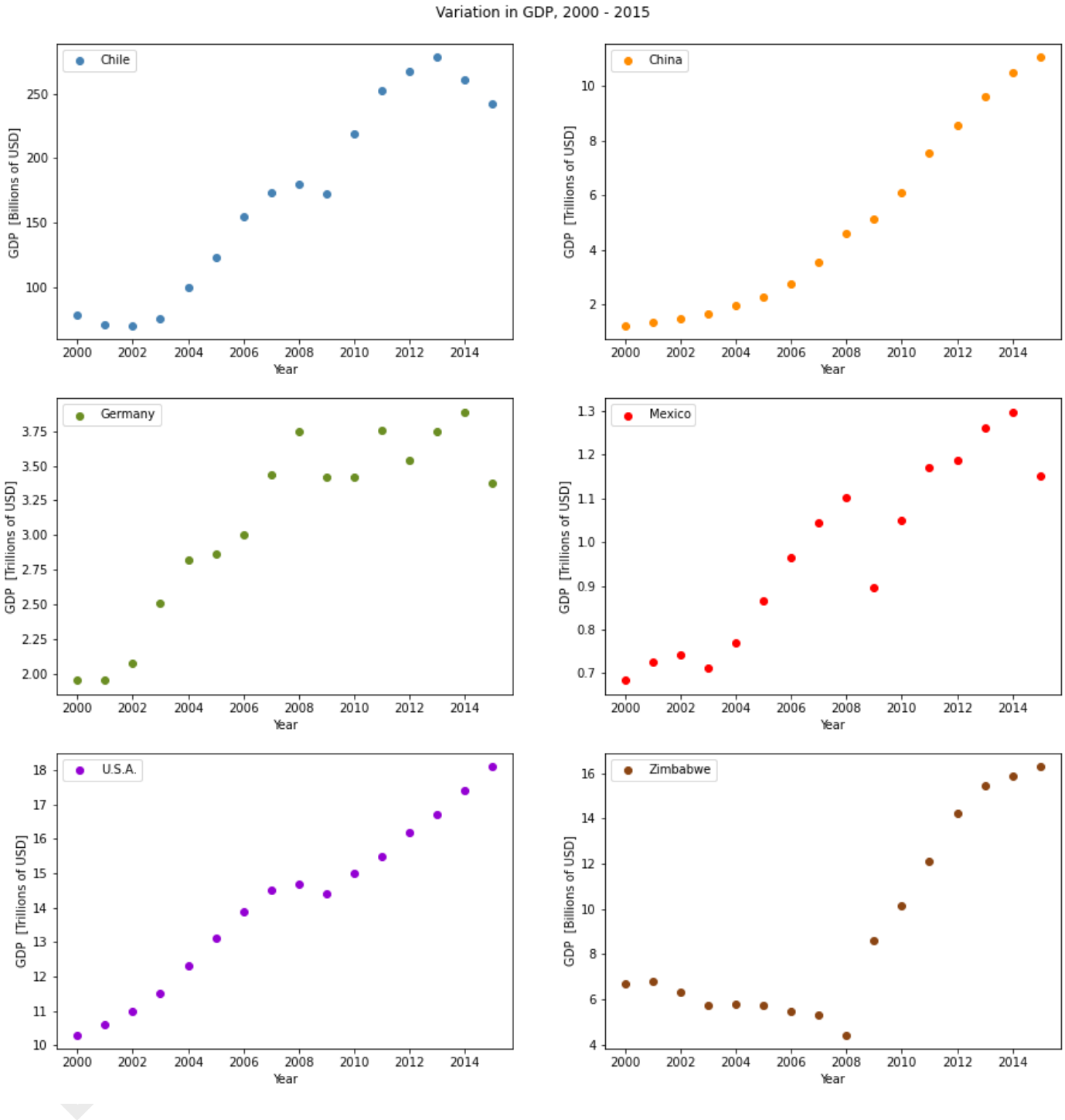
The first thing to notice about this plot is that the five largest economies have the highest life expectancies. The smallest economy—Zimbabwe—has the lowest life expectancy. This matches our naïve hypothesis that the higher a country's GDP, the higher its life expectancy. However, there's clearly more to the story than that. Take a look at those five largest economies again and note how their average life expectancy values are all around the same value. China and Mexico's life expectancies are a little bit lower than the others, sure, but they're all pretty comparable. Now remember that the United States (the U.S.) had by far and away the highest average GDP of all six nations, while Chile's average GDP was roughly 1/100 that of the U.S. Yet, both countries have comparable average life expectancies; indeed, Chile's average life expectancy is *higher* than that of the U.S.! Germany's average life expectancy is higher than the U.S.'s as well. So just having a sky-high GDP isn't enough to make your average life expectancy at birth the highest in the world. Some other factors must be at play.

What can we take away from what we've learned so far? First, up to a point, the higher a country's GDP the higher its average life expectancy tends to be. This matches our initial idea of what should happen. But when you look at some of the highest global GDPs, the average life expectancies tend to clump together, so very high GDPs don't necessarily translate into very high life expectancies. Thus, comparing the largest economies amongst themselves, there doesn't seem to be a correlation between GDP and life expectancy. Something other than money available to spend on health services and/or to increase quality of life must be at play.

Change in GDP Over Time

As I mentioned when we started looking at average GDP and average life expectancy at birth for the six nations I have data for, 15 years of data is a long timeframe to average over. The average GDPs I calculated smooth over recessions (like the "Great Recession" in the U.S. in 2008), wars (like the one Zimbabwe engaged in with the Democratic Republic of the Congo between 1998 and 2002), natural disasters, and other significant events. Meanwhile, advancements in medical technology over 15 years could have a positive impact on life expectancy, while disease outbreaks and pandemics could negatively influence it. To get a better idea of how GDP and life expectancy relate, it's good to look at how they've each varied with time over the 15-year period this data spans. Do both quantities increase over time? Does one increase while the other decreases? Do they both decrease with time? Seeing how GDP and life expectancy each trend over time can give us some indication of how they are related.

Let's look at the variation in a nation's GDP from 2000—2015 first, since we looked at average GDP first above. I will do separate plots of GDP vs. time for each country; in those plots, for each year that a GDP is reported I will plot its value as a data point. Wait, why not plot the data as lines, you might ask? It's a personal preference of mine. Line plots to me imply inferences about what the data is doing "in between" data points (i.e., when we connect the dots with line segments) when in fact we may not know that for sure. I think it is better to plot the data points themselves and look for overall trends based on them. So with that in mind, what is the trend of GDP with time for these six nations? The plot is far too big to fit on this page, so I will include it on the next one.



It's important to note a couple of things about these plots before we delve too deeply into what they tell us. First, the scale of the vertical axis for each nation's GDP plot is different: that is to say, they don't all cover precisely the same range. One of the reasons I did not plot all of the data in one figure is that the scale is so different between the smallest GDP and the largest GDP that any time variation in any nation's data would be washed out by having to include values in the billions of U.S. dollars and tens of trillions of USD on the same plot. (Admittedly, I could have done

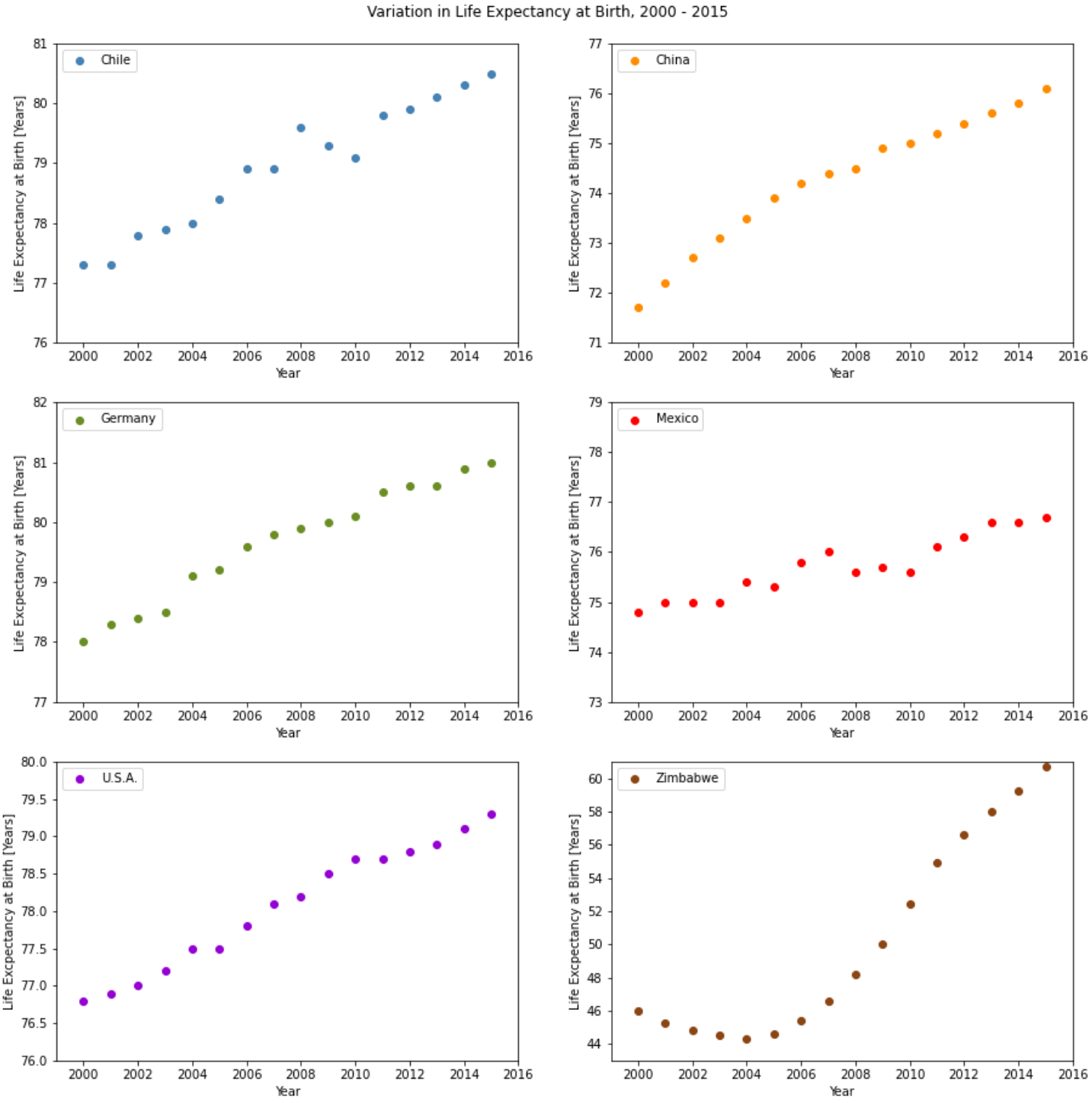
a semi-log plot, but those can be hard to interpret.) Thus, the scales of the vertical axis of Zimbabwe's GDP plot and that of the U.S.'s GDP plot are quite different, and you should bear that in mind while looking at these plots. Also, note that I plotted Chile's GDP data in billions of U.S. dollars rather than trillions of U.S. dollars; I think it's a little easier to process 200 billion than it is to process 0.2 trillion. The last thing to note is that I have "zoomed in" on the data to make time variations easier to see, but that can exaggerate the scale of variation in your mind as you look at the plot. In other words, while it looks like the GDP in Mexico took a huge nosedive in 2009, the GDP only went down by 12.5%. And what looks to be a crazy big fluctuation in the GDP of Germany between 2008 and 2015 only corresponds to a 9% overall difference.

With these caveats in mind, one thing is abundantly clear: in the five biggest economies (corresponding to the highest GDPs), GDP largely trended upward with time. The GDPs of the U.S. and Chile showed minor blips during the "Great Recession" of 2008, but otherwise steadily increased with time. (The GDP of Chile also had a minor downturn between 2000 and 2002 as its economy recovered from the Asian financial crisis of the late 1990s.) Mexico's GDP also took a dip in 2008, and appeared to be on a downturn by 2015, but showed distinct periods of growth with time otherwise. Meanwhile, the GDP of Germany grew pretty steadily until 2008 or so, but after that it seemed to level off. By contrast, China exhibited steady growth in GDP over the entire 15 years. Thus, in large part, GDP tended to grow with time for the 5 largest economies.

Zimbabwe's data tells a much more complicated story tied to its economic and political history. Its GDP shrank steadily from 2000 until 2008, then increased sharply starting in 2009. What happened in 2009 that sparked a marked increase in Zimbabwe's GDP? I'm hardly an expert on international affairs or international business, but was able to do a little bit of research into what happened in Zimbabwe between 2000 and 2010. My primary source of information was Wikipedia, which while not an acceptable source for academic research at least allowed me to gain some general understanding of the broad issues at hand. The initial decline in GDP seen from 2000 to 2002 was likely related to the war Zimbabwe was engaged in with the Democratic Republic of the Congo. But the same time (and continuing until 2008 or so), the Zimbabwean government's land reform program (which allowed for the confiscation of farmlands owned by white farmers) and price control policies, as well as sanctions imposed against the Zimbabwean government by Western nations, had a detrimental effect on the economy[3]. This combination of factors, as well as governmental mismanagement and corruption[4], led to a period of high inflation culminating in the hyperinflationary period of the mid-2000s[5]. To counteract this, Zimbabwe's finance minister in 2009 announced a new policy which permitted Zimbabweans to use other currencies, in addition to the Zimbabwean dollar, to conduct business[6]. Between the adoption of currencies besides the Zimbabwean dollar and the policies of the Unity Government elected in 2008[7], the economy rebounded and Zimbabwe's GDP began growing again. Zimbabwe's political and cultural history is much richer and more nuanced than the extraordinarily brief four-sentence summary of the years 2000—2009 that I've attempted, yet the impact of governmental policy on GDP is clear. At least between 2009 and 2015, Zimbabwe's GDP grew yearly, despite the earlier decline in GDP from 2000 through 2008.

Change in Life Expectancy at Birth Over Time

So that's what GDP did over the entire 15-year timeframe. What did life expectancy do? Did it also increase, or did it decrease? Maybe it was pretty flat with time? Let's construct plots of life expectancy at birth vs. time for each of the six nations we've looked at so far. Again, I will plot each nation's data as data points, and each nation will have its own plot. Let's have a look at that figure below:



The same cautions that I gave about the GDP vs time graph apply here: namely, each country's plot has its own vertical axis scale, so not all plots have the same range in life expectancy; and, I've zoomed in on the data, which tends to exaggerate the size of fluctuations in life expectancy with time … as well as the overall change in it, in this particular case. First, we should note that, for all nations, life expectancy at birth increased with time. For the U.S. and Germany, that increase was fairly steady, but it wasn't big; life expectancy at birth only rose by 3 years over the 15-year timeframe of the data. Mexico's life expectancy also didn't change much—only a 2½ year increase—but did experience a period of downturn between 2008 and 2010. Chile's average life expectancy at birth took a little while to recover from the "Great Recession" of 2008, but increased by 4 years over the 15-year timeframe. China's life expectancy at birth steadily increased the entire 15 years and rose by 6 years between 2000 and 2015. Zimbabwe's life expectancy at birth again tells a much more complicated picture, one that is not only tied to its economic and political history but also to the tragic occurrence of disease outbreaks in the country. I again did some cursory research on Wikipedia into why Zimbabwe's life expectancy at birth may have declined from 2000 to 2006 or so, and was sobered by how hard-hit the country has been by acute disease outbreaks. Like most of Africa, Zimbabwe was still experiencing the effects of the HIV/AIDS pandemic of the 1990s during the early 2000s, but it was also hard-hit by a cholera epidemic in 2008 and 2009[8]. (Zimbabwe was also hit by a plague outbreak in 1994, before the timeframe of this dataset.) The effects hyperinflation on the country's health services appear to have been catastrophic, as the healthcare system seems to have collapsed in the mid-2000s—this is evidenced by hospital closures and drug and medicine shortages[9]. (Of course, the effects of hyperinflation were seen in Zimbabwe's yearly GDP above.) Fortunately, the same economic policy reforms which helped Zimbabwe's GDP recover also aided the recovery of the healthcare system[10], and the resultant gains in life expectancy at birth since 2009 are readily apparent in the previous plot.

What have we learned from these plots of GDP vs. time and life expectancy vs. time? First, we've seen that GDP tended to increase over time in Chile, China, Germany, Mexico, and the U.S.; life expectancy at birth also increased over time in those nations. Hence, both GDP and life expectancy increased with time: that is to say, they both trended in the same direction. This is a good indication that they may be correlated! Zimbabwe's plots of GDP over time and life expectancy over time told a complicated story, but the changes in GDP and the changes in life expectancy broadly trended the same way: when GDP decreased with time, so did life expectancy at birth. When GDP increased, so did life expectancy. This is more evidence that GDP and life expectancy could be correlated.

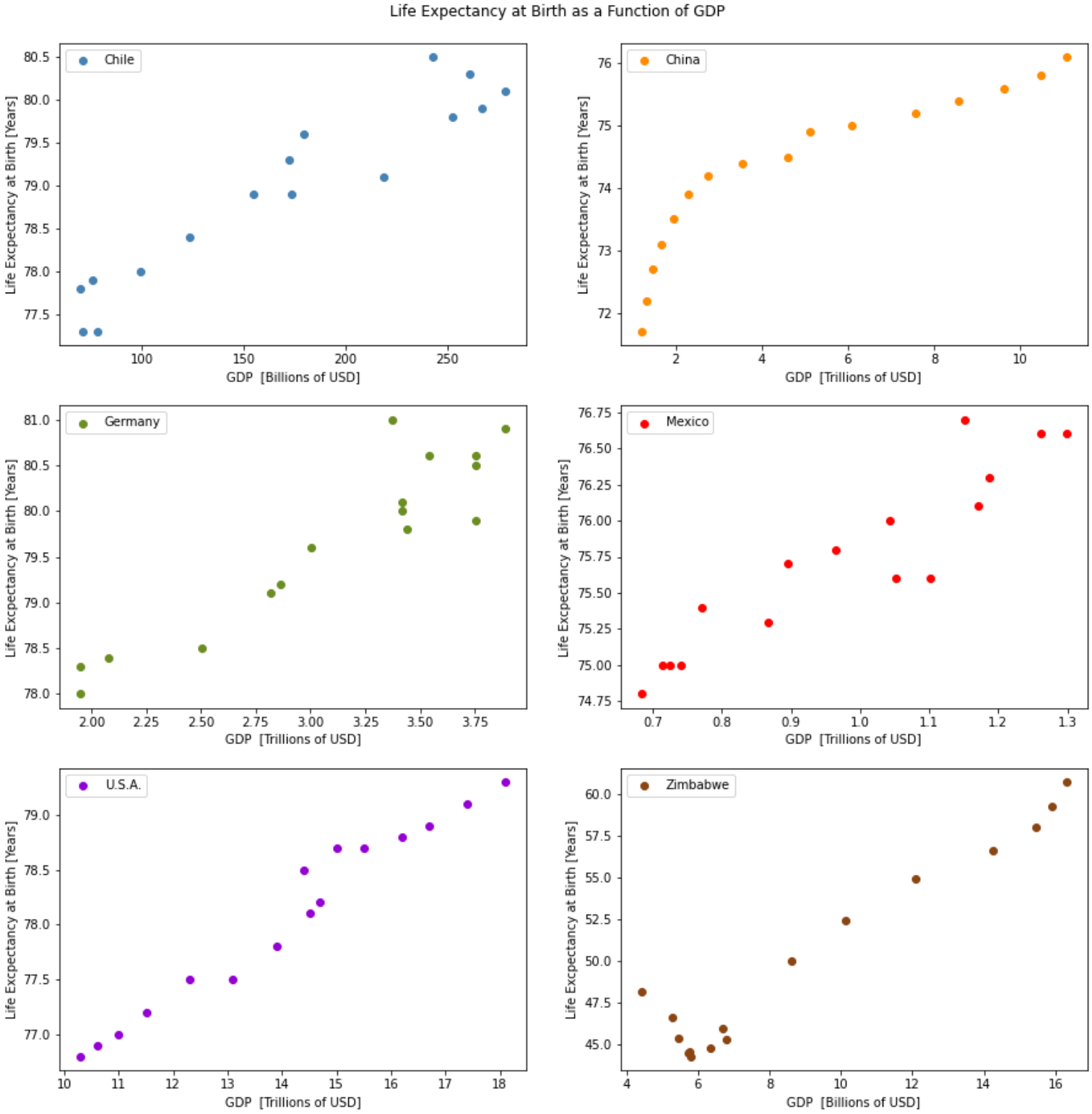
Does Life Expectancy at Birth Correlate with GDP?

We've already seen that life expectancy at birth and GDP trend the same way over time: when one goes up, so does the other; when one goes down, so does the other. Both quantities depend on time, and both trend with time in the same broad way. But it could also be that life expectancy is influenced directly by GDP and not just by both quantities depending on time in the same way. As discussed above, life expectancy can be influenced by changes in quality of life and/or changes in access to health services, among many other factors. And since a nation's GDP could possibly influence both its quality of life and its spending on health services, it stands to reason

that life expectancy at birth could be sensitive to changes in GDP. If this is true—that life expectancy is sensitive to changes in GDP—we should be able to see evidence of a positive (or negative) correlation if we plot life expectancy vs. GDP.

Let's put a little thought into this plot before we make it. When making a scatter plot, it is customary to plot the independent variable on the horizontal axis of the plot. Since our hypothesis is that life expectancy is sensitive to GDP, it makes sense to treat GDP as our independent variable. This automatically makes life expectancy at birth our independent variable, which is customarily plotted on the vertical axis. (Thus, my convention in naming scatter plots is to name them "dependent variable vs. independent variable.") For each nation, we have 16 unique GDP/life expectancy data point pairs—one for each year from 2000 to 2015—and it is those data points which shall form the basis of our scatter plots. Since GDP and life expectancy are pretty much continuous quantities, we shouldn't run into the problem of having more than one life expectancy value correspond to the exact same GDP value, although I suppose it could be possible. The only way to find out for sure is to actually construct the plot; I've placed it on the next page, as it's a rather large one and couldn't fit on the remainder of this one.

While the scatter plots seen on the next page display many interesting features, one thing is clear: life expectancy at birth tends to be higher when GDP is higher. In other words, life expectancy and GDP look to be positively correlated (when one goes up, so does the other) as we look at the broad trends of each plot. There is a bit of an exception to this trend when looking at Zimbabwe's data; life expectancy looks to be negatively correlated with GDP between GDP values of about 4 billion and about 6 billion U.S. dollars, but shows a positive correlation for higher GDP values. None of the data appear visually to follow a straight line, although the plot for the U.S. comes the closest. China's plot shows the least variation from a smooth curve, whereas Mexico's curve is very bumpy and contains a couple of plateaus. There's also a lot of scatter at the low-GDP and high-GDP ends of Chile's scatter plot, which could impact our attempts to get a more quantitative idea about how GDP and life expectancy at birth are correlated, if at all.


Life Expectancy at Birth as a Function of GDP
Chile
Life Excpectancy at Birth [Years]
GDP [Billions of USD]
China
Life Excpectancy at Birth [Years]
GDP [Trillions of USD]
Germany
Life Excpectancy at Birth [Years]
GDP [Trillions of USD]
Mexico
Life Excpectancy at Birth [Years]
GDP [Trillions of USD]
U.S.A.
Life Excpectancy at Birth [Years]
GDP [Trillions of USD]
Zimbabwe
Life Excpectancy at Birth [Years]
GDP [Billions of USD]

Why should we try to get a quantitative value for how GDP and life expectancy at birth are correlated? Isn't it clear from the plot that they are? Well, yes, visually the two quantities look to be correlated; but our eyes could be inferring trends that, mathematically speaking, aren't really there. To get a good idea of whether or not GDP and life expectancy are actually correlated, and a feel for how strongly they are correlated, we should look at ways to test for correlation mathematically. There are two widely used options: the Pearson correlation coefficient (*r*) and the Spearman rank correlation coefficient (ρ). Both values tell you how positively correlated two quantities are; however, the Pearson correlation coefficient tells you about their linear correlation[11], whereas the Spearman rank correlation coefficient indicates how well the curve can be described by a monotonic function[12]. I calculated each coefficient for each of the six nations, as there is no *a priori* reason to expect GDP and life expectancy to be linearly related. Here are the Pearson *r* coefficients and Spearman ρ coefficients for the data from each nation:

Nation	Pearson *r* coefficient	Spearman ρ coefficient
Chile	0.95	0.93
China	0.91	1.0
Germany	0.93	0.85
Mexico	0.93	0.92
the U.S.	0.98	0.99
Zimbabwe	0.97	0.75

These numbers are great and all, but how should we think about them? Let's look at the *r*-coefficient first. Loosely speaking, it tells us how closely the data follow a straight line. The closer the *r*-coefficient is to 1, the more closely the data follow a straight line. Surprisingly, it looks as though the life expectancy vs. GDP plots of all six nations can be well described by a straight line, as all *r*-coefficients in the table above are higher than 0.9. China's *r*-coefficient is the lowest at 0.91, which is unsurprising since that plot visually deviated most from a straight line; the *r*-coefficient of the U.S.'s plot is the highest, again unsurprising since this plot visually deviated least from a straight line. As for the ρ-coefficient, it very loosely tells us how strong the trend in the data is; more specifically, the closer the ρ-coefficient is to 1, the more perfect the monotonic relationship between the variables. As for what a monotonic function is, Wikipedia describes it as a function that is either entirely non-increasing or entirely non-decreasing[13]. (Here, non-decreasing just means the function never decreases; it can increase or "flatten out", it just can't decrease[14].) Take the plot of China's life expectancy at birth vs. GDP: it looks like it flattens out a bit between 3 and 5 trillion USD, but it never decreases; hence, it is an entirely non-decreasing function and has an ρ-coefficient of 1. Zimbabwe's GDP does decrease between 4 and 6 billion USD, but increases at higher GDP values, hence its low ρ-coefficient. The mess at GDP values greater than 3.50 billion USD contributes to Germany's ρ-coefficient of 0.85; all other nations' ρ-coefficients indicate strong but imperfect monotonicity. All told, the numbers in the table above indicate that life expectancy at birth and GDP are indeed correlated, over half the time monotonically, and that the life expectancy vs. GDP plots of all nations can be well described by a straight line. Thus, we have confirmed that life expectancy and GDP are in fact correlated.

Fitting a Trendline to the Data

In the previous section, we saw that the Pearson correlation coefficients of plots of life expectancy at birth vs. GDP for all six nations were larger than 0.9, indicating that the data could be well-described by a straight line. So, let's add straight lines to our plots of life expectancy at birth vs. GDP to see how good a fit they seem to be! We can't just add any old straight line, of course; we need to figure out the equations of the lines which best fit the data and add those lines of best fit to our plots.

What is a line of best fit? Basically, it's the line that best expresses the relationship between points on a scatter plot[15]. I will find the lines of best fit for each of the life expectancy vs. GDP plots I made above using linear regression, which uses a least-squares approach to calculate the slope and intercept of that best-fit line[16]. It's worth noting that the best-fit lines I come up with are just empirical relations between GDP and life expectancy at birth as fit to the data; they should not be thought of as some "law" which tells exactly how life expectancy at birth depends on GDP, nor as a hard and fast mathematical rule which gives you an exact life expectancy given a particular GDP value. To the best of my knowledge, there is no theory which predicts a linear relationship between GDP and life expectancy at birth based on proven relationships between the two quantities, so these lines should be seen as convenient descriptors rather than predictive rules.

With that description and listing of caveats out of the way, I'll use Scikit-Learn[17] and the life expectancy at birth vs. GDP data for each of the six nations to determine the best-fit lines which describe each nation's data. On the next page, I've included the plots of life expectancy vs. GDP that I made above but this time with the best-fit lines for each set of data included. Since we have one independent and one dependent variable, the lines of best fit can all be written in the following form

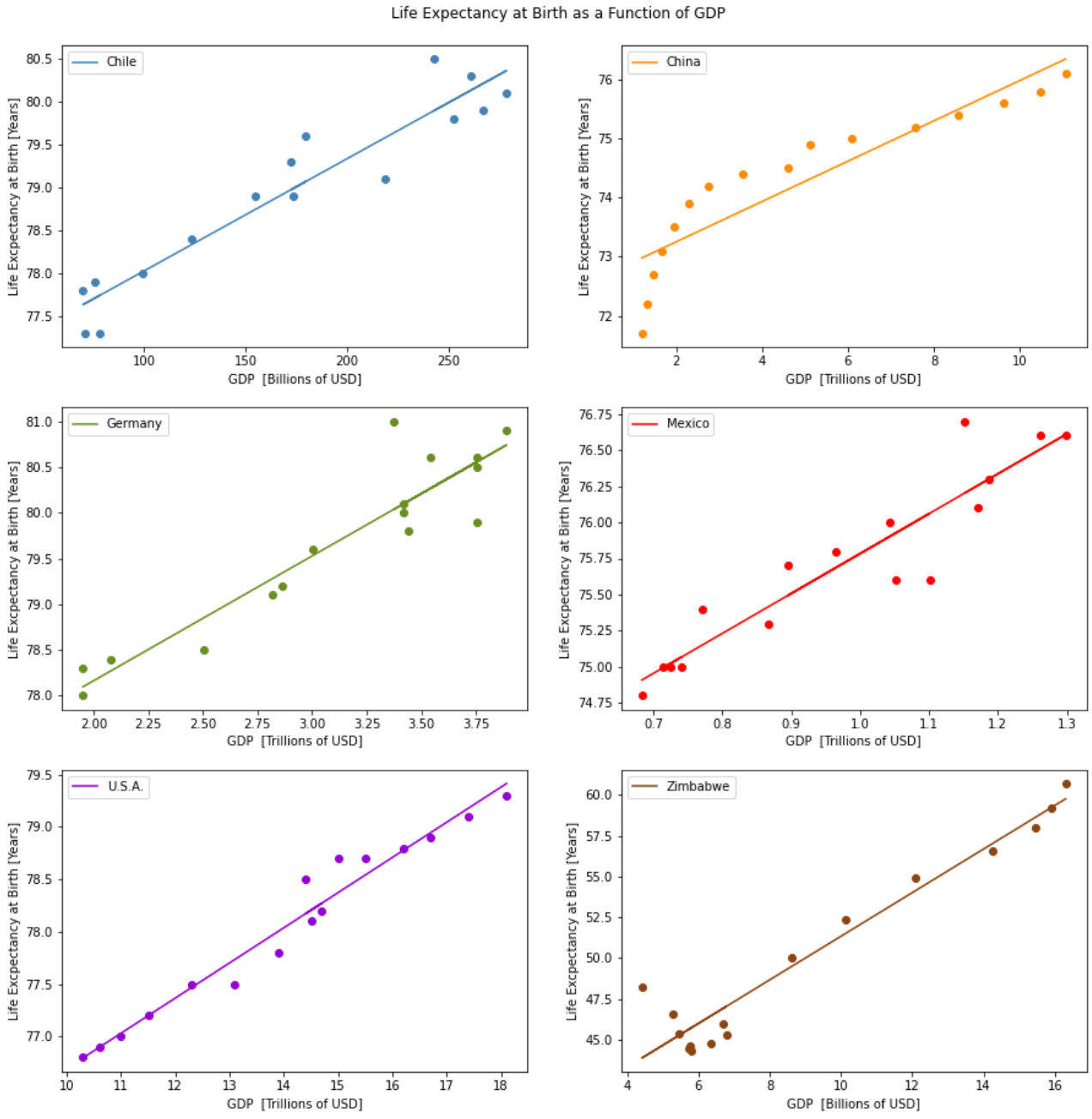
$$y = mx + b$$

where *y* represents life expectancy at birth, *x* represents GDP, *m* is the slope of the line, and *b* is its y-intercept. For the sake of completeness, here are the slopes and y-intercepts of the best-fit lines for each nation:

Nation	*m*	*b*
Chile	0.0131	76.7
China	0.342	72.6
Germany	1.36	75.4
Mexico	2.76	73.0
the U.S.	0.334	73.3
Zimbabwe	1.34	38.0

For these data, the slope of the best-fit line represents the change in life expectancy over the change in GDP, so it appears as though Mexico, Germany, and Zimbabwe have the biggest change in life expectancy given a unit change in GDP. It's also worth noting that Zimbabwe has

the smallest *y*-intercept value for its best-fit line, consistent with its average life expectancy being the smallest of the six nations being studied.



Conclusions

In this article, I explored the (naïve) hypothesis that a nation's life expectancy at birth is correlated with its Gross Domestic Product (GDP). I used a dataset which contained 15 years of GDP and life expectancy at birth data for Chile, China, Germany, Mexico, the United States of America, and Zimbabwe to test this correlation. I found that, at least for the data compiled in this dataset, life expectancy at birth and GDP are in fact positively correlated: as GDP increases, so does life expectancy at birth. There was one exception to this trend: for Zimbabwe, for small values of GDP, GDP and life expectancy at birth were negatively correlated. What's more, the life expectancy at birth vs. GDP data could be well-described by a straight line, and I used the linear regression package in Scikit-Learn[18] to determine what that line of best fit was. I also investigated how GDP and life expectancy at birth changed with time for each of the six nations in the dataset, and delved into how the political and economic history of Zimbabwe impacted observed trends in GDP and life expectancy at birth over time.

While I was able to confirm the hypothesis that a nation's life expectancy at birth is correlated with its GDP, that's about all I could investigate with this particular dataset. There's only so many questions one can answer when your data consists only of a country's name, the year for which data was compiled, the country's life expectancy at birth for that year, and its yearly GDP for that year. Further, the conclusions I reached are only true for the six nations studied and may not hold up if data from the other 189 nations on Earth were included. It would've been nice to have annual GDP and life expectancy at birth data for more nations, to ensure a more robust conclusion about the correlation between life expectancy at birth and GDP. However, while the above two limitations of the data put severe restrictions on the broader applicability of the conclusions I reached, it was an easy dataset to work with and allowed a meaningful investigation into the six countries chosen for inclusion.

References:

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2: https://www.investopedia.com/ask/answers/what-is-gdp-why-its-important-to-economists-investors/

3: https://en.wikipedia.org/wiki/Economy_of_Zimbabwe and https://en.wikipedia.org/wiki/Zimbabwe#Economy, and references therein.

4: https://en.wikipedia.org/wiki/Zimbabwe#Economy

5: https://en.wikipedia.org/wiki/Zimbabwe#Economy

6: https://en.wikipedia.org/wiki/Zimbabwe#Economy

7: https://en.wikipedia.org/wiki/Zimbabwe#Government_and_politics

8: https://en.wikipedia.org/wiki/Zimbabwe#Health

9: https://en.wikipedia.org/wiki/Zimbabwe#Health

10: https://en.wikipedia.org/wiki/Zimbabwe#Health

11: https://en.wikipedia.org/wiki/Pearson_correlation_coefficient

12: https://en.wikipedia.org/wiki/Spearman%27s_rank_correlation_coefficient

13: https://en.wikipedia.org/wiki/Monotonic_function

14: https://en.wikipedia.org/wiki/Monotonic_function

15: https://www.investopedia.com/terms/l/line-of-best-fit.asp#:~:text=Line%20of%20best%20fit%20refers,calculations%20or%20regression%20analysis%20software

16: https://en.wikipedia.org/wiki/Linear_regression#:~:text=In%20statistics%2C%20linear%20regression%20is,as%20dependent%20and%20independent%20variables

17: https://scikit-learn.org/stable/

18: https://scikit-learn.org/stable/