

Is Gross Domestic Product (GDP) an adequate measure of Environmental sustainability and Human Well-Being

Dhimant Ananmay, Yoojin Kim, Yiu Ting Leung, Sanurak Natnithikarat, Irah Shaikh

Introduction

“It [GDP] measures everything in short, except that which makes life worthwhile.” - Bobby Kennedy

Economic growth is an increase in the production of economic goods and services that a society produces and consumes. Economic growth has increased the living standards around the globe. However, economists have lost sight of the fact that gross domestic product (GDP) is only capable of measuring the overall size of an economy. GDP does not reflect a nation's overall development and welfare. Yet, economists often utilize GDP as an all-encompassing measurement to signify a country's development and progress. When the status of a country is mentioned in a conversation its GDP is often used as the common descriptor of how “developed” or “underdeveloped” a country is. However, our group knows that the story is never that simple – that focusing only on GDP as an indicator to measure economic growth ignores climate change, sustainability and human well-being. This project provides a great opportunity for us to explore the limitations of GDP, so that GDP can take into account a nation's quality of life.

The GDP fails to address several factors that we now take into consideration for how “well off” a country is. As Kapoor Debroy points out within “GDP Is Not a Measure of Human Well-Being” that “GDP by definition is an aggregate measure that includes the value of goods and services produced in an economy over a certain period of time. There is no scope for the positive or negative effects created in the process of production and development.” We now live in a world where the social, physical, mental and environmental benefits of the goods and services catered to us are highly scrutinized. Yet none of these aspects are accounted for within the GDP. Along with that Kapoor and Debroy also point out how “GDP also fails to capture the distribution of income across society – something that is becoming more pertinent in today's world with rising inequality levels in the developed and developing world alike.”

Because GDP is no longer the best way to measure a country's “wellness,” several are now looking for new scales of measurement. The Human Development Index, for example, has gained notability as a fairer indicator for a country's development. Still, a common issue with HDI was its lack of environmental measures. Jin and others, however, have proposed a new index to solve this issue. They “[propose] a new National Sustainable Development Index (NSDI)” which modifies the HDI and adds “more comprehensive sustainability perspectives” (Jin, 1). It is suggested that “sustainable development is to coordinate economic, social, and environment development, to balance intra-generational welfare, and to maximize the total welfare of generations” and thus these aspects are vital and should be included in an index that measures the overall welfare of a country (Jin, 17).

Within this final project, our group will use the exploratory data available to us in order to analyze the relationship between several variables and their relationship with GDP in order to further prove the incapability of GDP to fully recognize a country's well being or even prove how it really only focuses minute cases of progress while turning a blind eye to others.

The variables we are going to explore in this project are from the World Bank:(World Bank Metadata)

Log GDP: Gross domestic product (GDP) in constant 2010 U.S. dollars. GDP is the sum of gross value added by all resident producers in the economy plus any product taxes. **One potential issue of GDP data our group discusses is that GDP is calculated without making deductions for depletion and degradation

of natural resources. Besides, even though the GDP is collected in 2018, the Data is still converted from domestic currencies using 2010 official exchange rates. The exchange change may have changed drastically in those year after 2010.

Fish_threatened: Number of fish species classified by the IUCN as endangered, vulnerable, rare, indeterminate, out of danger, or insufficiently known. The International Union for Conservation of Nature (IUCN) Red List of Threatened Species collects and disseminates information on the global threatened species. ** One potential issues is that there are limitation to the current IUCN data set. Our group discuss that although The IUCN Red List is able to show us the current status of fish species, it cannot be interpreted as an overall assessment of the nation's biodiversity.

Life_expectancy_total: Life expectancy at birth, total (years). Life expectancy at birth indicates the number of years a newborn infant would live. ** One potential issues is that it does not include non-fatal health issues and it only take into account of the prevailing patterns of mortality at the time of its birth.

Mammals_threatened: Number of mammal species classified by the IUCN as endangered, vulnerable, rare, indeterminate, out of danger, or insufficiently known. The International Union for Conservation of Nature (IUCN) Red List of Threatened Species collects and disseminates information on the global threatened species. ** One potential issues is that there are limitation to the current IUCN data set. Our group discuss that although The IUCN Red List is able to show us the current status of Mammals species, it cannot be interpreted as an overall assessment of the nation's biodiversity.

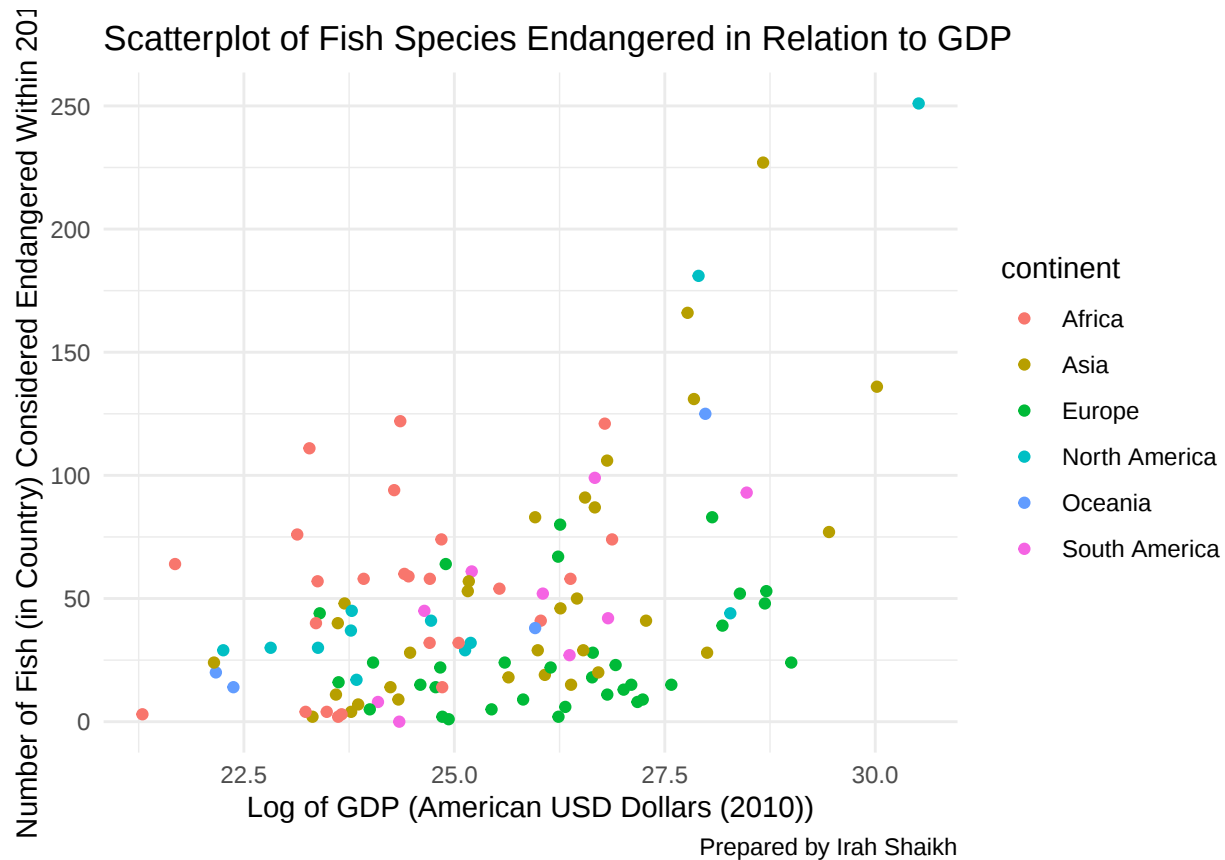
Legal_rights: This strength of legal rights index measures the degree to which collateral and bankruptcy laws protect the rights of borrowers and lenders and thus facilitate lending. The index ranges from 0 to 12 with higher scores indicated that these laws are better designed to expand access to credit

Labor: Labor force total of people ages 15 and older who supply labor for the production of goods and services during a specified period. This includes people that are currently employed and people who are unemployed but seeking work and first-time job-seekers. Notice, however, that unpaid workers, family workers, and students are omitted.

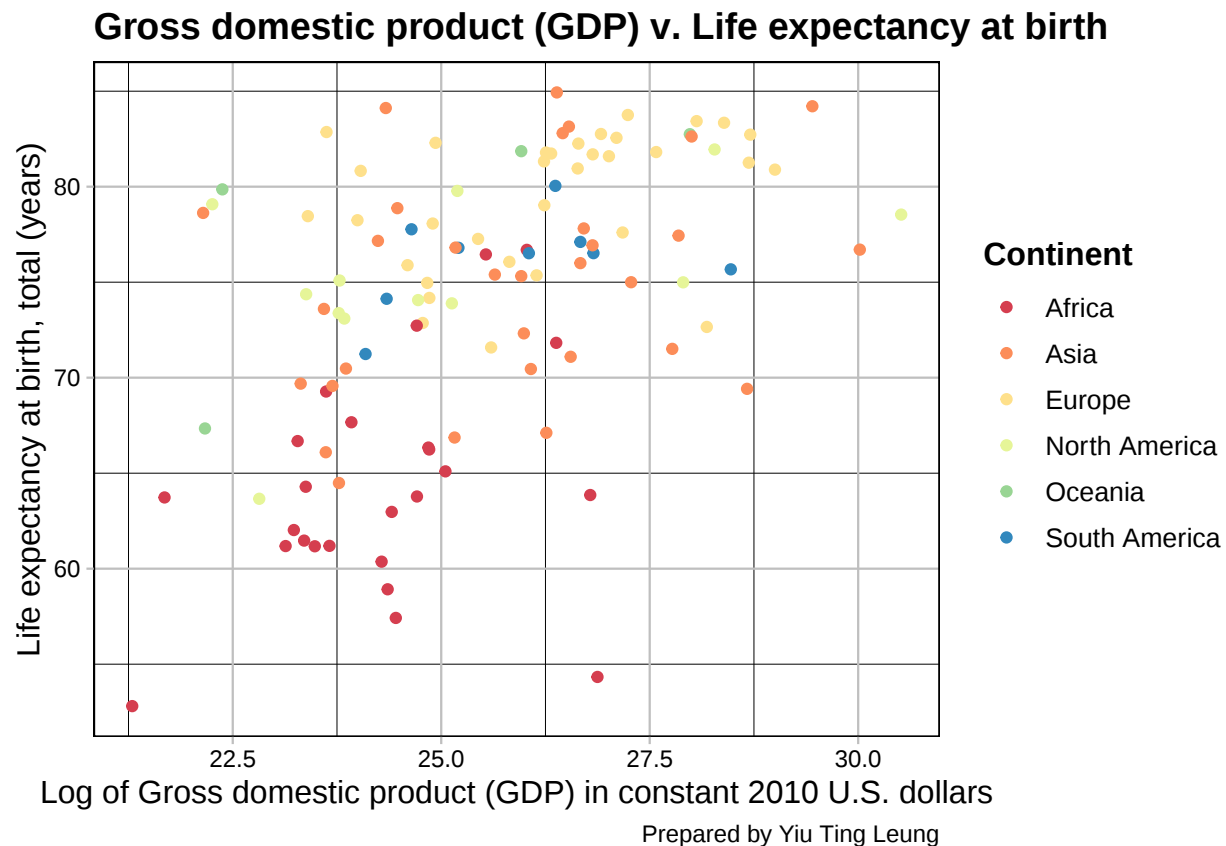
Mobile_cell: Number of subscriptions to a public mobile telephone service that provide access to the PSTN using cellular technology

Exploratory Data Analysis/ Description of Data

Exploratory Data Analysis - Irah Shaikh



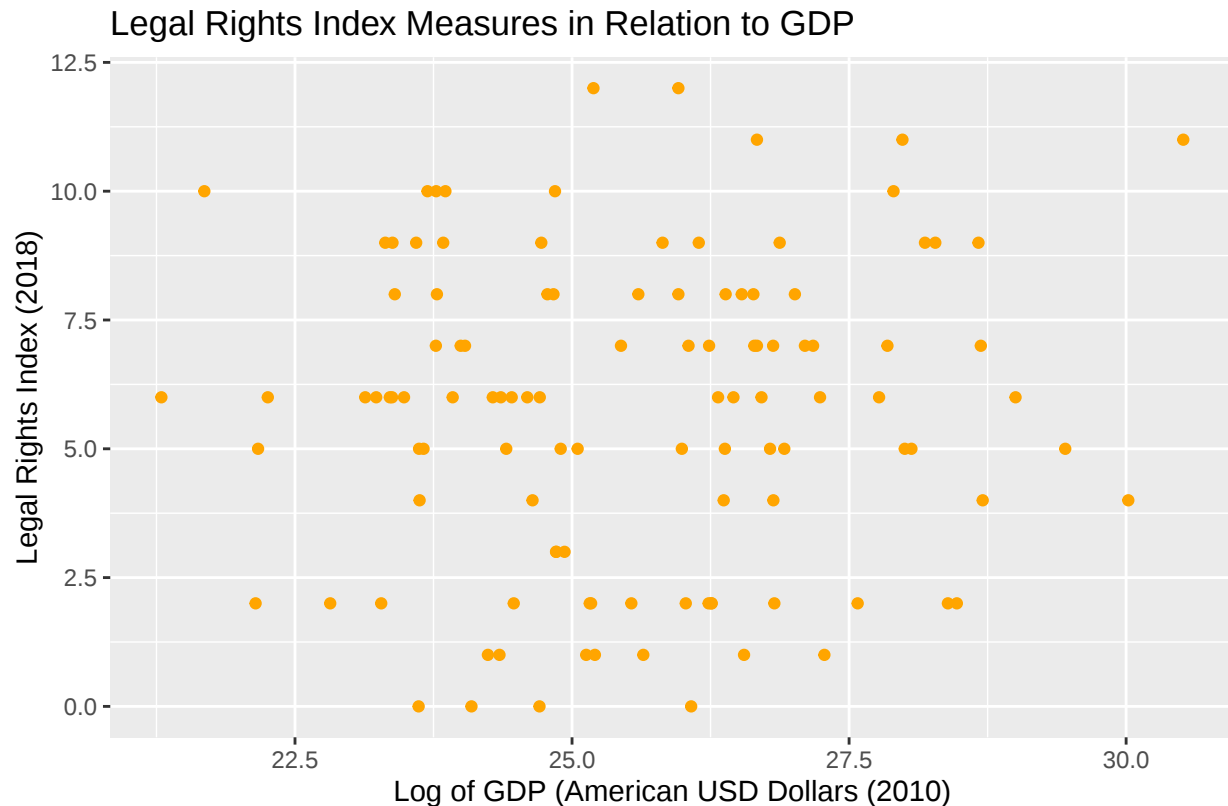
As depicted above we decided to plot the number of fish species considered endangered within a country over the Log of GDP of each country during the year of 2018. When the countries themselves were plotted by continent a majority were clustered to the bottom of the scatter plot due to not having large GDP's in comparison to countries that make up a large amount of the world market such as the US or China that were outliers and altered the scatter of the plot. Despite this it can be seen that there is a very weak positive correlation in terms of a country's GDP and how many fish species are considered endangered within the country. It was interesting to see how Europe tended to stay along the bottom of the graph, suggesting the country itself does not have a big fishing industry or are strict with policies protecting the environment no matter the country's GDP. Meanwhile countries in Africa had lower GDP but higher cases of fish species endangerment; suggesting the lack of action on enacting policies to protect the environment, a heavy fishing industry, or perhaps other factors as well such as many other countries within Africa having easy access to the ocean. Policy reform (with heavy environmental focus), geography, industry specialization all have impacts on how the relationship between the two factors are impacted. Overall, however, it's clear that although GDP is a good indicator for environmental impacts of deterioration for some countries, it is not for all. This indicates how the GDP does not accurately take into consideration the environmental factors and their effect on a country's well being. This extremely weak positive trend helps open up the discussion as to how accurate the GDP truly is.



Life expectancy is a pivotal indicator to measure the human well-being of a nation. We aim to try and identify the relationship between the GDP and Life Expectancy at birth for every nation in 2018 with the help of data visualization. We use life expectancy at birth as a proxy of population health. Total life expectancy at birth refers to how long, on average, a newborn can expect to be alive, if current death rates remain constant. We understand that health is a multi-dimensional concept and life expectancy at birth is one of the most frequently used health indicators of population health and human well-being of a country. Life expectancy is effective as it reflects the overall mortality level of a population, and summarizes the mortality pattern that prevails across all age groups in a given year. High life expectancy at birth can be connected to a number of factors, such as increasing living standards, improved lifestyle, and better access to education. Life Expectancy at birth is presented as a total and is measured in years.

We first plot a scatter plot with the natural logarithm of GDP in the x-axis and the life expectancy at birth in the y-axis. The graph illustrates that there is a positive correlation. As countries have a higher GDP, their life expectancy also increases. The graph indicates that individuals born in richer countries with higher GDP, on average, can expect to have higher life expectancy than those born in poor countries with lower GDP. Life expectancy is profoundly lower for countries with lower levels of GDP. Developed countries with high GDP, such as Japan, Germany, and France, their life expectancy are also higher. Developing countries with low GDP, such as Barbados, Fiji, Maldives, and Liberia, their life expectancy are also lower. The Central African Republic has the lowest life expectancy and also lowest GDP.

Exploratory Data Analysis - Yoojin Kim,



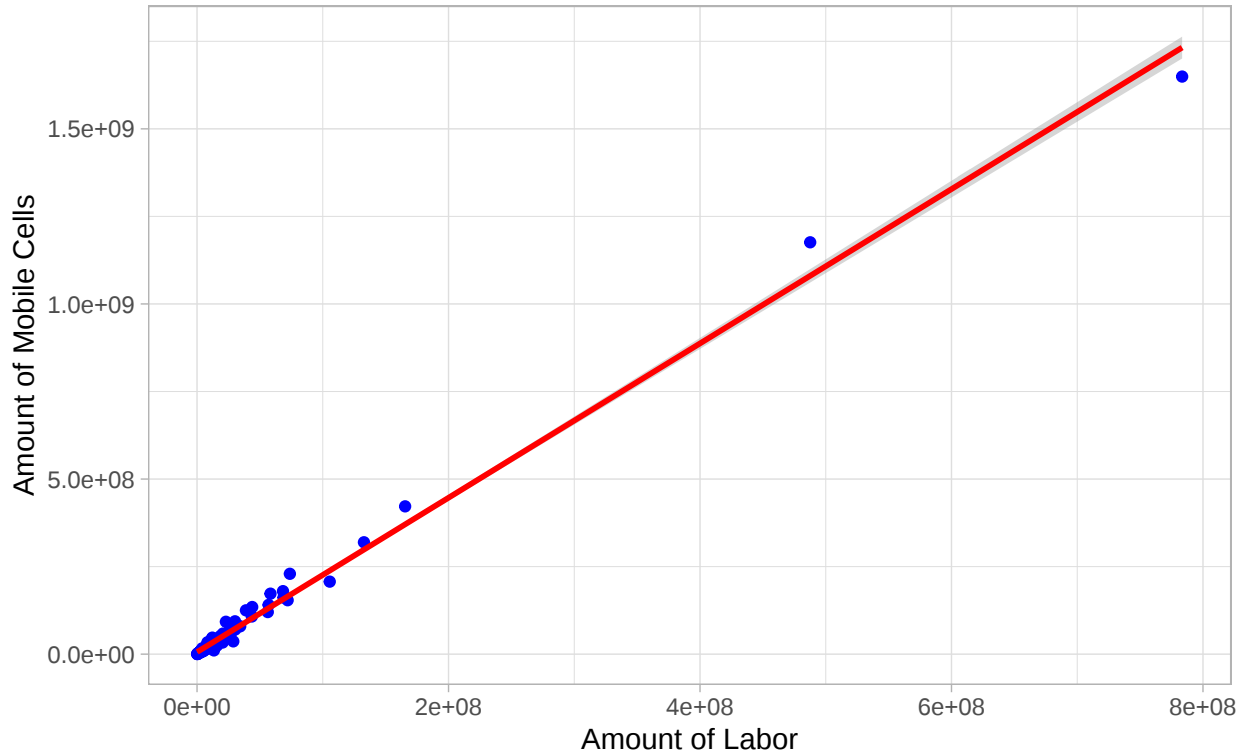
index ranges from 0 to 12 with higher scores indicated that these laws are better designed to expand access to credit

The analysis depicts the relationship between legal rights and economic development by assessing the strength of legal rights in terms of GDP per country. The index used to measure the degree of law protection is scored from 0 to 12, with higher scores indicating that laws are better designed to expand access to credit. It measures the degree to which collateral and bankruptcy laws protect the rights of borrowers and lenders and facilitate safe lending in the credit market. While a prosperous business environment is expected to employ protection and establish institutions to reduce uncertainty and risk in the country, the graph above claims differently. The correlation between the legal rights index and GDP is weak, meaning that these variables are loosely correlated. Capital market development, predominantly evaluated through GDP, has little to do with the protection and enforcement of legal rights. In fact, the average for 2018 based on 120 countries was 5.53 points. The highest value was in Australia and United States: 11 points and the lowest value was in Iraq. This proves that the determinant factor that affects the legal rights may remain outside the GDP since protection of legal rights is associated with political instability, social unrest, and government policies. This ties to our initial question that the gross domestic product (GDP) fails to capture the full picture of legal protection and legal rights in the capital market system.

Exploratory Data Analysis - Sanurak Natnithikarat,

Analysis: Sanurak Natnithikarat

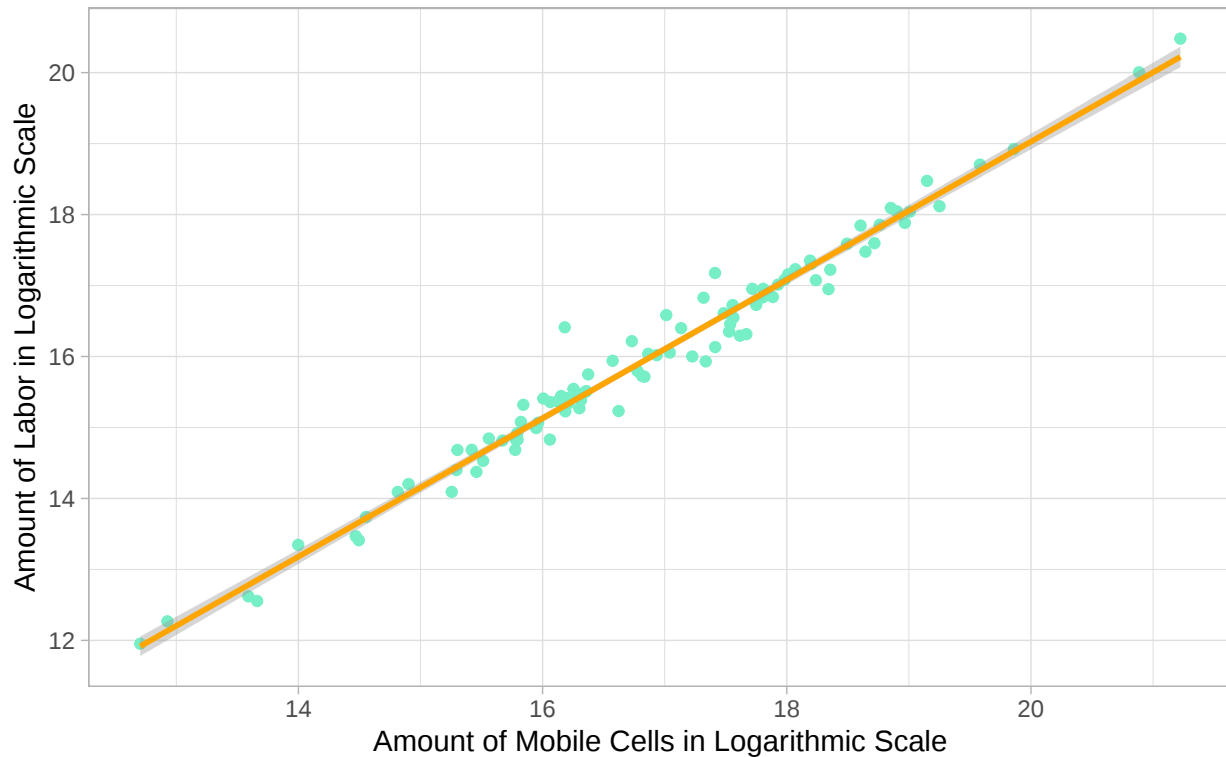
Mobile Cell Ownership vs Labor
 $r = 0.996$



After taking a quick look at the correlation matrix that I have created, I found that there is an interesting relationship between mobile cell ownership and labor. The correlation matrix indicates that there is a very strong correlation of almost 1. Therefore I decided to explore the relationship between these two variables. I first decided to visualize the scatterplot between the two variables and realized that there are two extreme point which could heavily influence the data and the correlation between these two variables. The extreme points on the scatterplot indicates that there are extreme values on the right end of both variables– the histogram of each variable will be skewed right. Because of this, I decided to normalize both variables by taking the logarithm of them. After doing a log transformation of both data. With this logarithmic transformed data, I created a new scatterplot and a new linear regression line between $\log(\text{labor})$ and $\log(\text{mobile_cell})$

Mobile Cell Ownership vs Labor in Logarithmic Scale

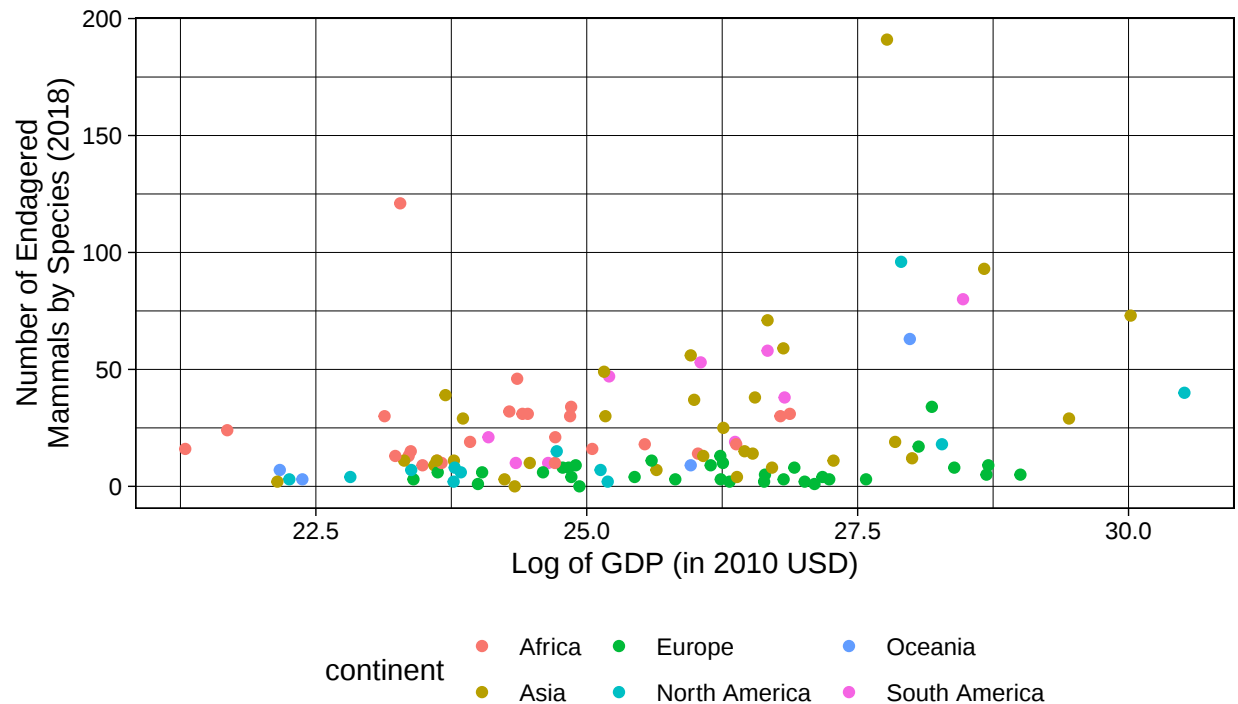
$r = 0.988$



With this, a new scatter plot with no outliers still shows a very strong linear relationship with a correlation coefficient of 0.988. This ensures that the high correlation is an interesting one that we might want to explore further. The labor data provided by the Worldbank is the total amount of workers who are over 15 years old and supply labor for the production of goods while subscriptions to mobile_cell is the total amount of registered mobile plans in each country. This relationship may suggest that mobile-cell has become a crucial part of our lives to the point that it so strongly correlate with the number of labors. It could be that mobile-cells have become not just a luxury but a necessity for work. To further examine whether or not mobile-cells have become a necessity in all countries, regardless of ability to afford mobile phones, we could categorize countries into ranges of GDP to gain a better insight about the strength of this trend in different economic settings.

Exploratory Data Analysis - Dhimant Ananmay

Number of Endangered Mammals in Relation to GDP



Prepared by Dhimant Ananmay

Here we've plotted the log of GDP of each country (arranged by continent) against the number of endangered mammal species within it. We can see a weak correlation between the number of mammals endangered in a country and the relative strength of its GDP. It is interesting to note that Europe tends to have relatively strong GDPs while having the minimum number of endangered species while on the other hand, the majority of African nations have a higher number of endangered species and weaker GDPs. I believe this is an indication of the available resources for a country that can be allocated to natural conservation. However, the increased propensity of African economies to contain endangered species may be a reflection of the ubiquity of wildlife in the region as well as its relative lack of urbanization. Similarly, the large variance in endangerment within Asia and South America may result from geographical determinism and not socio-economic choices. Additionally, the lack of control for geographical size and aggregate biodiversity makes it difficult to gauge the proportional significance of endangerment levels.

Data Analysis

This is the section for formal data analysis. This should be where you answer your main question(s) of interest. This section should include regression and a hypothesis test (possibly HT for slope of regression line). You might also include additional plots.

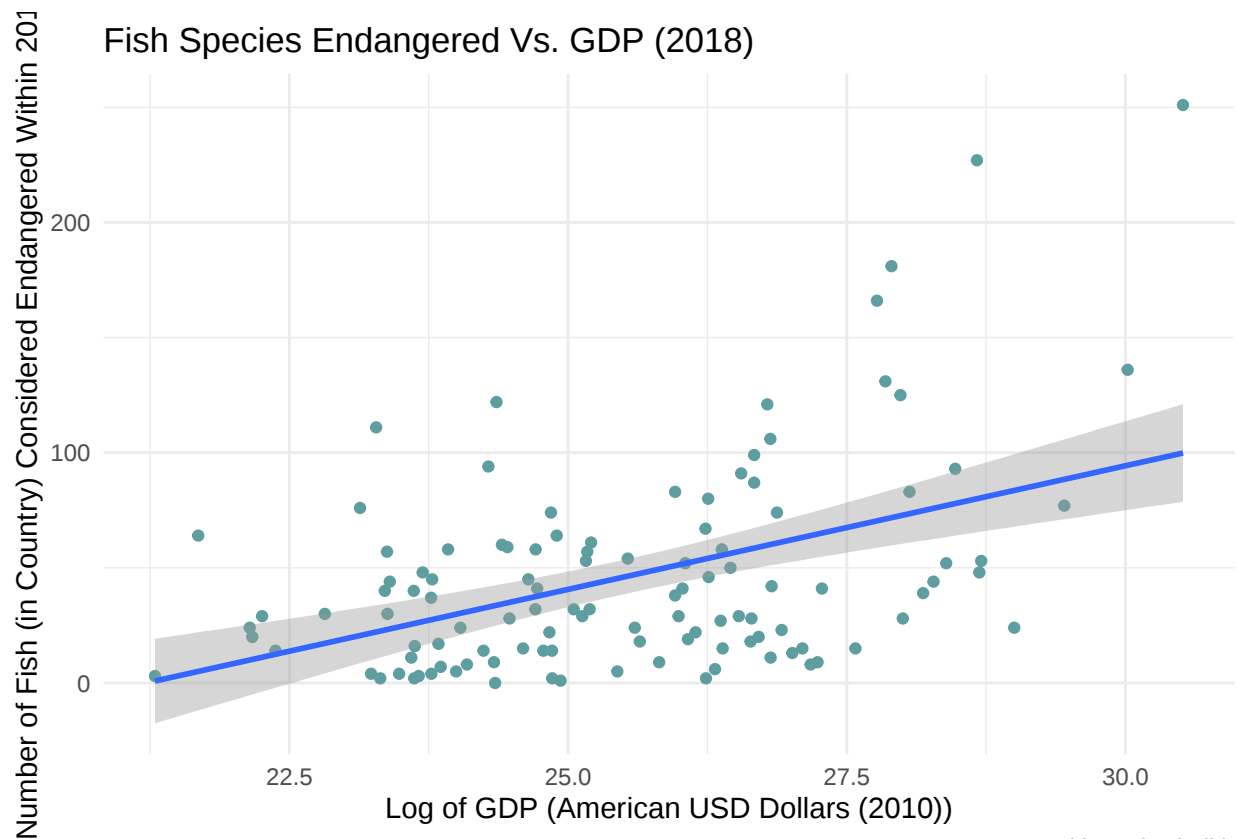
You should show:

- any math you do for your hypothesis tests (including formulas, p-values, etc)
- plots that explain what you see (if you're looking at correlations)

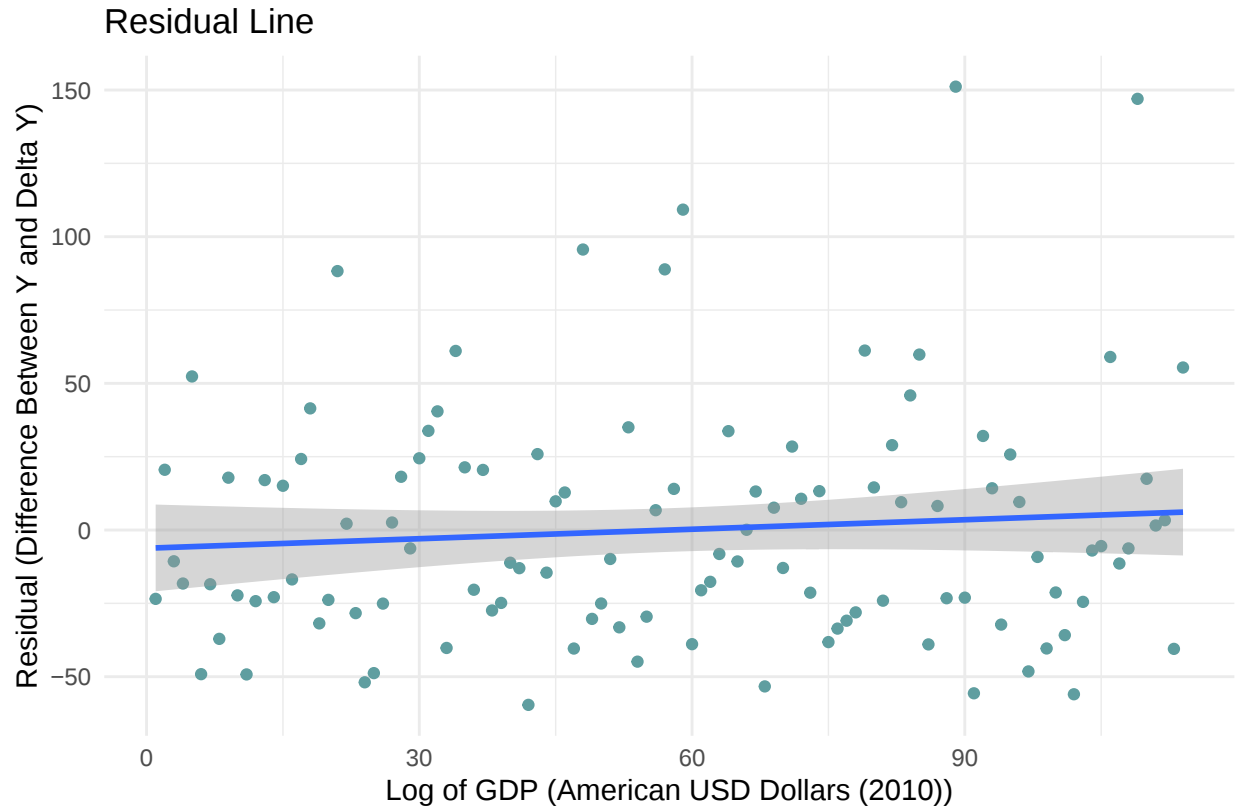
Data Analysis: Research Question 1: GDP and Environmental Sustainability - Deep Dive into the Relationship between GDP and Number of fish species classified by the IUCN as endangered.

Regression

```
##
## Call:
## lm(formula = fish_threatened ~ wb18_adjGDP, data = wb18_adj)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -59.603 -26.838  -9.521  18.074 151.146
##
## Coefficients:
##              Estimate Std. Error t value Pr(>|t|)
## (Intercept)  -227.784     51.236  -4.446 2.07e-05 ***
## wb18_adjGDP    10.737      2.003   5.361 4.49e-07 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 40.25 on 112 degrees of freedom
## Multiple R-squared:  0.2042, Adjusted R-squared:  0.1971
## F-statistic: 28.74 on 1 and 112 DF,  p-value: 4.487e-07
```



Prepared by Irah Shaikh



Hypothesis Test

```
## [1] "Pooled SE: 8.10462775124419"
```

```
## [1] "t-statistic: 3.12578616944427"
```

```
## [1] "p-value: 0.00112950293944158"
```

Our first research question investigates the relationship between economic activity and environmental sustainability by assessing the number of endangered fish species in each country. This is a valuable indicator of the environmental conditions available to a given population due to its extensive impact on nutritional access and biodiversity. Despite the urgency of environmental degradation, we expected the high opportunity cost of environmental sustainability to be a considerable barrier for developing countries.

For the hypothesis test, the null hypothesis is that the Number of fish species classified by the IUCN as endangered in country with high GDP is equal to the Number of fish species classified by the IUCN as endangered in country with low GDP. The alternative hypothesis is that the Number of fish species classified by the IUCN as endangered in country with high GDP is greater than the the Number of fish species classified by the IUCN as endangered in country with low GDP. The Pooled SE is 8.10462775124419. The t-statistic is 3.12578616944427. The p value is 0.00112950293944158. Thus, we reject the null hypothesis.

For linear regression, our data analysis employs linear regression to measure the strength of this correlation in the year 2018. The positive skew of the regression line indicates that there is a positive association between the endangerment of fish species and GDP. However, the R-squared value is 0.202, which enables us to infer that these variables are only weakly correlated. Additionally, the magnitude of residual error increases as we move further from the median GDP, presumably since the data is clustered around this region. This may

suggest the presence of confounding factors such as geographical size that may be better correlated with endangerment.

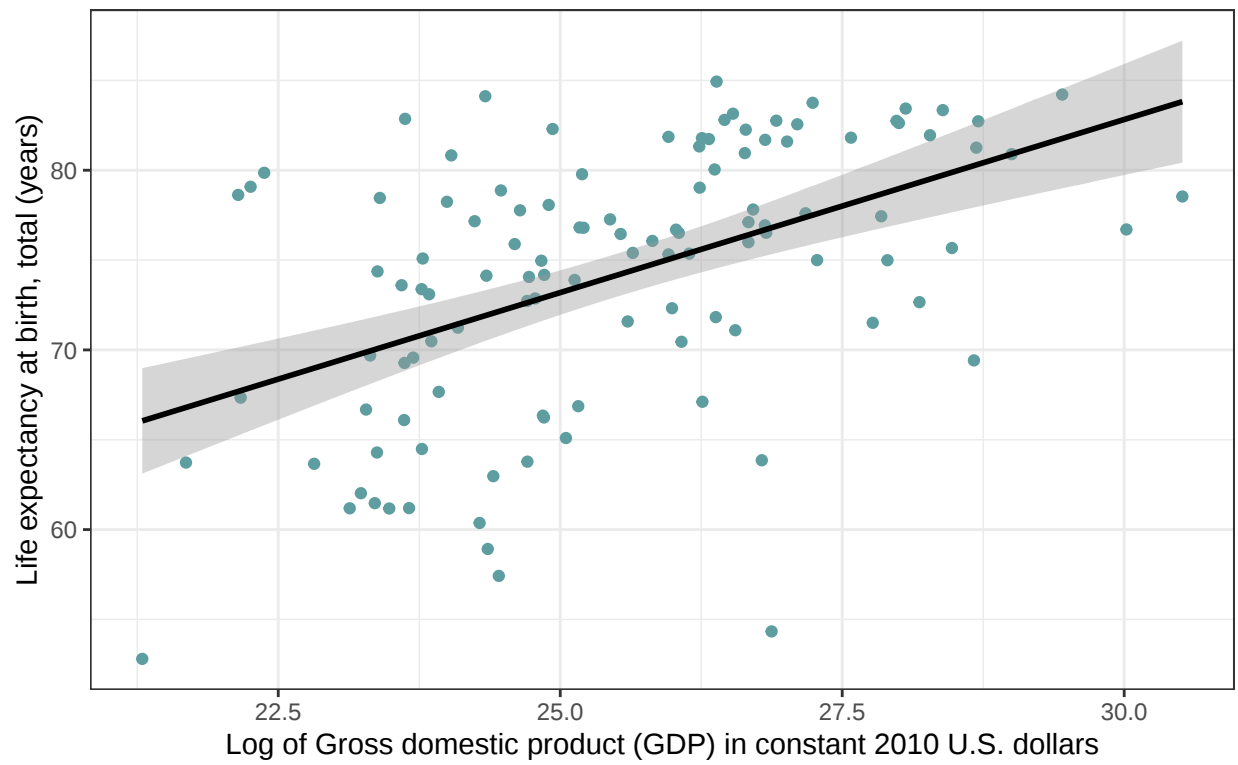
The overall standard residual error for this dataset is 40.25 given 112 degrees of freedom, which is relatively high since the majority of countries have less than 100 endangered species. Consequently, we cannot report a significant correlation between these variables.

Data Analysis: Research Question 2: GDP and Well-Being - Deep Dive into the Relationship between GDP and life expectancy

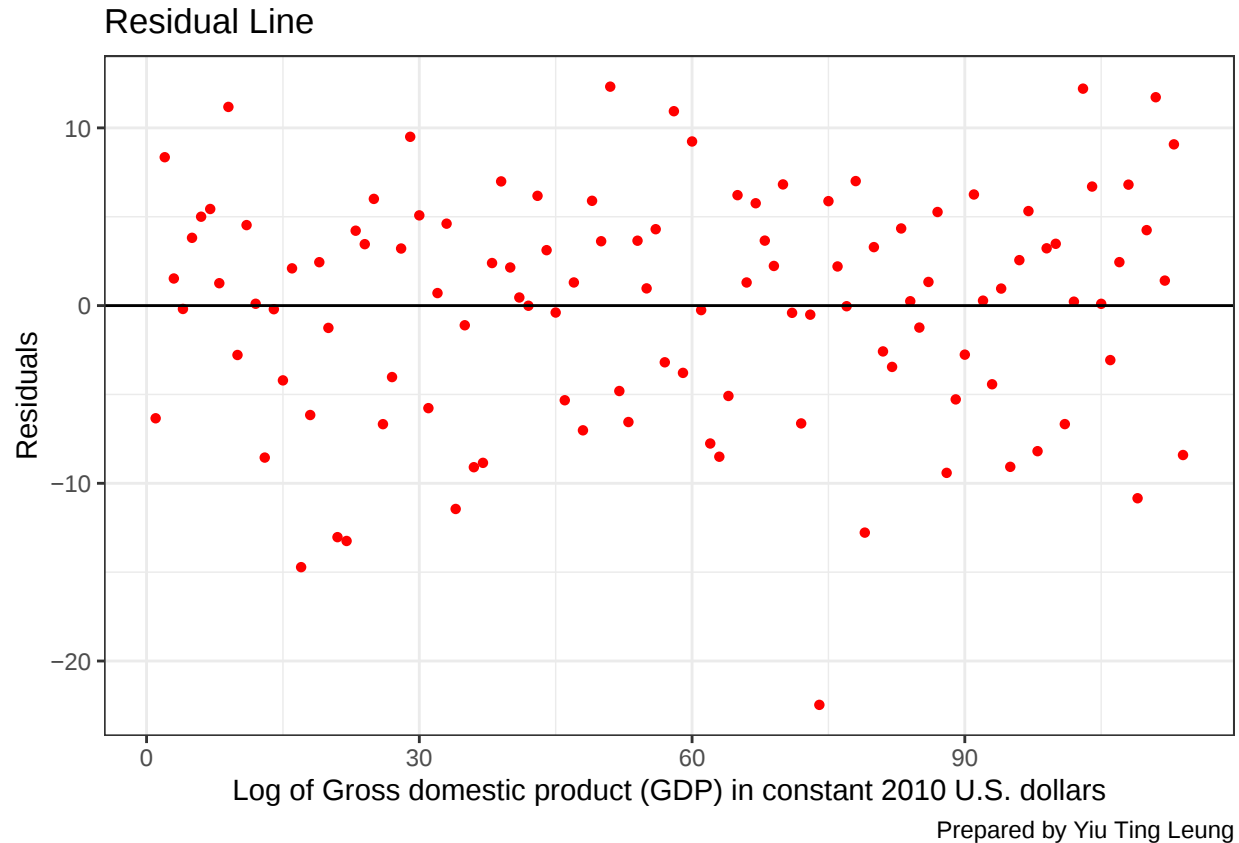
Regression

```
##
## Call:
## lm(formula = life_expectancy_total ~ wb18_adjGDP, data = wb18_adj)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -22.4685  -4.3724   0.9636   4.3302  12.3209
##
## Coefficients:
##              Estimate Std. Error t value Pr(>|t|)
## (Intercept)  25.0227     8.2036   3.050  0.00285 **
## wb18_adjGDP   1.9267     0.3207   6.009 2.38e-08 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 6.444 on 112 degrees of freedom
## Multiple R-squared:  0.2438, Adjusted R-squared:  0.237
## F-statistic: 36.1 on 1 and 112 DF, p-value: 2.378e-08
```

Gross domestic product (GDP) v. Life expectancy at birth



Prepared by Yiu Ting Leung



Hypothesis Test

```
## [1] "Pooled SE:  1.22927130737928"

## [1] "t-statistic:  5.54935321060984"

## [1] "p-value:  1.94443712686621e-07"
```

For our next research question, we investigate the relationship between gross domestic product (GDP) and life expectancy. Life expectancy at birth indicates the number of years a newborn infant would live if prevailing patterns of mortality at the time of its birth stay the same throughout its life. Using the graph from our exploratory data analysis, our group decided that a regression line and residual analysis in regression should be used to analyze the association between GDP and life expectancy at birth.

When our group explores the relationship between GDP and life expectancy in the above exploratory data analysis, we are able to observe a positive association between these two variables. This enables us to believe that a linear regression model will be suitable for us to explore the data in detail. To our knowledge, we expect a higher GDP will be associated with higher life expectancy at birth as nations with higher GDP have better healthcare, improved lifestyle, and better access to education.

For the null hypothesis test, we test whether country that has higher GDP will have different life expectancy than country with low GDP. The null hypothesis is that life expectancy in country with high GDP is equal to life expectancy in country with low GDP. The alternative hypothesis is that life expectancy in country with high GDP is different than life expectancy in country with low GDP. The Pooled SE is 1.22927130737928. The t-statistic is 5.54935321060984. The p value is 1.94443712686621e-07. Therefore, we reject the null hypothesis. That means life expectancy in country with high GDP is different than life expectancy in country with low GDP.

Now, we will take a look into the regression result. The correlation coefficients are used to measure how strong a relationship is between two variables. It also measures clustering around a line, relative to the SDs. As illustrated in the graph and R, the correlation coefficient r is equal to 0.4937, which demonstrates a moderate correlation. The residual plot as illustrated shows no trend. The residuals and the predictor variable are uncorrelated.

Conclusion

To investigate if Gross Domestic Product (GDP) is an adequate measure of environmental sustainability and human well-being, we focused on the relationship between GDP and endangered species, legal rights, life expectancy, mobile cell ownership, and labor.

From our initial data exploration, we investigated if GDP is a good indicator of Environmental Sustainability by analyzing the relationship between GDP and the Number of fish and mammal species classified as endangered. After normalising GDP using a log transformation, we still see that the coefficient of determination is 0.2042, meaning the linear regression can only explain 20 percent of the relationships between the two variables. This strongly suggests that GDP is not a good predictor of environmental sustainability. Nonetheless, after creating a hypothesis test for the difference of mean number of fish species endangered of countries with GDP above the median and below the median, we were able to get conclusive result that rejects the null hypothesis. With a p-value of 0.00113, we can be confident that the difference of mean number of endangered species is not 0 between countries with GDP greater than the median and countries with GDP lower than the median. The fact that the regression line yields a weak correlation between GDP and number of fish endangered while the hypothesis test yields strong conclusive evidence. This led us to the conclusion that GDP may not be a good predictor of Environmental Sustainability, but it can be useful indicator.

Finally, we explored the relationship between difference gross domestic product (GDP) and various human well-being indexes such as life expectancy, protection of legal rights, and mobile cell usage. A positive correlation was found between GDP and life expectancy at birth, and we demonstrated a linear regression model to prove that a higher GDP will be associated with higher life expectancy at birth. This can be explained through developed countries providing better healthcare, improved lifestyle, and better access to education. However, we found out that economic development do not always guarantee an overall welfare of the country by analyzing the relationship between legal rights and GDP. The correlation between the legal rights index and GDP was weak, indicating that economic development does not ensure the protection and enforcement of legal rights of citizens. This ties to our initial question that the gross domestic product (GDP) fails to capture the full picture of well being and sustainability despite of the fact that GDP serves its job in compressing various information about a country into one number. We have concluded that GDP is not a descriptive and all encompassing indicator, but since it is so generalised, it can be powerful when used correctly.

Shortcomings:

The variable we heavily explored within this analysis was the GDP. Yet to even go ahead with our research our data for the GDP variable had to be adjusted through logarithmic alterations in the explanatory stage of our analysis. Because of this the true extent to how large the GDP was for a country was not fully visible within our plots and graphs. This may make it so that our correlations are higher than they should be. Along with this some countries had to be excluded from our data due to null values and this could possibly lead to a less representative analysis.

It is important to note we grouped our country's by continent for the convenience of legibility. Were we to simply graph by countries themselves we would have done a further analysis in terms of a country's GDP and other factors and whether GDP is representative or not.

References

Include any articles/website you've referenced (if applicable)

Jin, Hui et al. "A Global Assessment of Sustainable Development Based on Modification of the Human Development Index via the Entropy Method." *Sustainability* 12.8 (2020): 3251. Crossref. Web.

Kapoor, Amet, and Bibek Debroy. "GDP Is Not a Measure of Human Well-Being." *Harvard Business Review*, 4 Oct. 2019, <https://hbr.org/2019/10/gdp-is-not-a-measure-of-human-well-being>.

Bogdan Dima, Flavia Barna & Miruna-Lucia Nachescu (2018) Does rule of law support the capital market?, *Economic Research-Ekonomska Istraživanja*, 31:1, 461-479, DOI: 10.1080/1331677X.2018.1432371