

# Quality of Life by Country: A Clustering Analysis

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## Abstract

Example abstract text

## Background

The Centers for Disease Control and Prevention (CDC) has recently issued a report indicating that life expectancy in the United States has decreased in 2017 as compared to 2016, with the overwhelming majority of deaths caused by heart disease and cancer, arguably preventable illnesses (Murphy et al. (2018)). Given that the United States has the world's largest economy, this decline in life expectancy is particularly concerning, and indicates that national wealth may not be predictive of citizens' longevity (The World Bank (2018)).

As the world's economies trend toward globalism, there is increasing interest in understanding how these nations compare on key quality of life (QoL) factors, including but not limited to life expectancy. Several organizations report on QoL measures as they evolve, including among others the World Economic Forum (WEF), World Health Organization (WHO), and the United Nations Development Programme. The QoL measures reported by these bodies can be either unidimensional values or compound scores calculated from several factors of interest.

The objective of this analysis is to explore the relationships between key QoL indicators by country, with particular focus on how the United States ranks, through a series of visualizations and  $k$ -means clustering analyses.

## Methods

This analysis included country-level QoL indicators as described in Table 1.

**Table 1. Country-Level QoL measures.**

Measure	Single or Compound	Description	Source
Gross Domestic Product (GDP)	Single	Valued in \$US 2018	@worldbank_gdp
Infant mortality rate	Single	Number of infant deaths per 1,000 live births	@who_infantmort
Life expectancy at birth	Single	Expected life at birth, both genders	@who_life
Life expectancy at sixty	Single	Expected remaining life years at age 60, both genders	@who_life
Human Development Index (HDI)	Compound	Developmental level, scale of 0:1	@un_dvlpt_HDI_desc
Human Development Index (HDI)	Compound	Developmental category, four levels (low, medium, high, very high)	@un_dvlpt_HDI_desc
Social Progress Index	Compound	Social progress level, scaled from 0:100 and comprising three broad categories: basic human needs (e.g., nutrition, safety), foundations of wellbeing (e.g., basic knowledge, environmental quality), and opportunity (e.g., personal rights, freedoms)	@socialprog_desc
Global Gender Gap Index	Compound	Gender equality index, scaled from 0:1, based on measurements of gender-related gaps in such dimensions as economic participation, level of education, health and survival, and political offices held	@wef_gender_desc
World Happiness Score	Compound	Happiness score, scaled from 0:10, based on several factors including per-capita GDP, healthy life expectancy, social support, freedoms, and perception of corruption	@whr

Data for these measures was obtained for calendar year 2016 in `.csv` or `.xls(x)` formats. Additionally, dataframe containing country identifiers (full names and three-letter codes) was generated from the `countrycode` library to facilitate merging the datafiles into one dataframe.

### *Wrangling and Exploration*

Each country-level datafile was imported, wrangled as needed, then tested against the dataframe containing country identifiers via `anti_join()` to identify mismatches. Mismatching country names were manually recoded for each datafile, then all datafiles were merged using serial `left_join()` statements. Countries with wholly missing data were excluded. The resulting dataframe, titled `alldata`, is presented in Table 2.

**Table 2. `alldata` dataframe contents.**

Source	Variable Name	Description
Social Progress Imperative (2018)	SPI	Social Progress Index value (scale of 0:100)
The World Bank (2018)	GDP_USD_2018	2016 Gross Domestic Product (valued in \$US 2018)
The United Nations Development Programme (2018)	HDIrank	Human Development Index ranking
The United Nations Development Programme (2018)	HDIindex	HDI index value (scale of 0:1)
The United Nations Development Programme (2018)	HDI_cat	HDI index category (5 levels)
Helliwell, Layard, and Sachs (2018)	happiness	World Happiness Score (scale of 0:10)
World Economic Forum (2016)	gendereq	Gender Equality Index (scale of 0:1)
World Health Organization (2018b)	infantmort	Infant mortality rate
World Health Organization (2018a)	birth_MF	Life expectancy at birth, males & females
World Health Organization (2018a)	sixty_MF	Life expectancy at 60 years, males & females

At least one univariate visualization was generated for each variable in `alldata` via `ggplot()`, and a correlation matrix was produced to investigate pairwise relationships between continuous variables. Next, a series of ordered country-as-factor bivariate visualizations were created to explore the top and bottom 20 countries by ranking within each variable.

### *K-Means Clustering*

To assess how the United States compares to the rest of the world, a series of  $k$ -means cluster analyses was carried out.  $K$ -means clustering is described elsewhere; briefly, given bivariate data and a desired number  $k$  groups, this classification algorithm classifies the points in the two-dimensional plane to minimize the total within-cluster variation for all clusters (James et al. (2013)). This is an iterative process that works by establishing  $k$  centroids, classifying each point by which centroid is closest, then moving the centroids to the center of their corresponding clusters, and repeating the process. Iteration terminates when the centroids no longer move, and the classification established in this terminal iteration is the clustering.

The Human Development Index categorizes the world's countries into four developmental levels (low, medium, high, and very high); thus  $k$ -means clustering analysis was performed assuming 4 clusters. Missing values were excluded to ensure the clustering algorithm would run, and a function was written to subset the clustering dataset (named `clusterdata`) to the variables of interest for each  $k$ -means analysis. On each output plot, the United States was identified by an enlarged `geom_point()`.

### *Example Code*

For brevity, example code for wrangling, plotting, and clustering is presented here; full code is available in the GitHub repository for this report (Prioli (2018)).

The libraries required for this analysis were loaded as shown below.

```
library(tidyverse)
library(readxl)      # For importing .xls(x) datasets
library(lazyeval)    # For renaming columns in function
```

```

library(countrycode)      # For establishing uniform country identifiers
library(ggthemr)          # For prettifying output
library(gridExtra)        # For grid.arrange()
library(grid)             # For textGrob() to annotate grid.arrange() elements
library(kableExtra)       # For nicer output tables
library(GGally)           # For ggpairs() correlation matrix
library(wesanderson)      # For Wes Anderson palette

ggthemr("fresh")          # For prettifying plot framework
wes <- wes_palette("Darjeeling1", 5, type = "discrete") # Establishing color scheme for cluster plots

```

Code for establishing a crosswalk for country names and 3-letter codes:

```

countries_full <- codelist_panel %>%
  select(country.name.en, year, genc3c, iso3c, wb_api3c) %>%
  group_by(country.name.en) %>%
  mutate(maxyr = max(year)) %>%
  ungroup %>%
  mutate(maxyr = case_when(
    maxyr == year ~ 1,
    TRUE ~ 0
  )) %>%
  filter(maxyr == 1) %>%
  select(-maxyr) %>%
  distinct()

countries_full <- countries_full %>%
  mutate(country3 = case_when(
    iso3c == genc3c & iso3c == wb_api3c ~ iso3c,
    is.na(iso3c) == FALSE ~ iso3c,
    is.na(iso3c) == TRUE & is.na(genc3c) == FALSE ~ genc3c,
    is.na(iso3c) == TRUE & is.na(genc3c) == TRUE & is.na(wb_api3c) == FALSE ~ wb_api3c
  )) %>%
  rename(country = country.name.en) %>%
  arrange(country)

countries <- countries_full %>%
  select(country, country3)

```

Code for importing and wrangling each data file, and standardizing country names (example shown for the Social Progress Index data):

```

# Importing, subsetting, renaming

SPI_2016_raw <- read_xlsx("data/SPIdata.xlsx", sheet = 4)

SPIdata <- SPI_2016_raw %>%
  select(2:3) %>%
  rename(`SPI` = `Social Progress Index`,
         country3 = Code)

# Standardizing country names by using `anti_join()` to see which
# countries in `SPIdata` don't have a match in the `countries` dataframe

SPIanti <- SPIdata %>%
  anti_join(countries, by = "country3") %>%
  select(country3) %>%
  arrange(country3) %>%
  unique()
dim(SPIanti)

```

```
## [1] 5 1
```

```
# Correcting for mismatches with `countries` using `mutate()`
```

```
SPIdata <- SPIdata %>%  
  mutate(country3 = case_when(  
    country3 == "CHI" ~ as.character(NA), # Nonstandard code for Chile; omitting (no data in these rows)  
    country3 == "KSV" ~ "XKS",           # Nonstandard code for Kosovo  
    country3 == "NCY" ~ as.character(NA), # Turk. Repub. of N. Cyprus; omitting (conflict w/Cyprus)  
    country3 == "SML" ~ as.character(NA), # Unable to determine  
    country3 == "WBG" ~ as.character(NA), # West Bank / Gaza Strip; omitting (conflict w/Palestine)  
    TRUE ~ as.character(country3)  
  )) %>%  
  filter(!is.na(country3))  
  
SPIanti <- SPIdata %>%  
  anti_join(countries, by = "country3") %>%  
  select(country3) %>%  
  arrange(country3) %>%  
  unique()  
dim(SPIanti)
```

```
## [1] 0 1
```

```
# Removing unneeded files
```

```
rm(list = c("SPI_2016_raw", "SPIanti"))
```

Code to combine individual data files into one dataframe and filter out countries with no data:

```
joindata_1 <- full_join(countries, HDIdata, by = "country")  
joindata_2 <- left_join(joindata_1, SPIdata, by = "country3")  
joindata_3 <- left_join(joindata_2, WHRdata, by = "country")  
joindata_4 <- left_join(joindata_3, genderdata, by = "country")  
joindata_5 <- left_join(joindata_4, infantmortdata, by = "country")  
joindata_6 <- left_join(joindata_5, lifeexpdata, by = "country")  
joindata_7 <- left_join(joindata_6, GDPdata, by = "country3")  
  
joinsub <- joindata_7 %>%  
  arrange(country) %>%  
  mutate(exclude_flag = case_when(  
    is.na(HDIrank) == TRUE &  
    is.na(HDIindex) == TRUE &  
    is.na(HDI_cat) == TRUE &  
    is.na(SPI) == TRUE &  
    is.na(happiness) == TRUE &  
    is.na(gendereq) == TRUE &  
    is.na(infantmort) == TRUE &  
    is.na(birth_MF) == TRUE &  
    is.na(sixty_MF) == TRUE &  
    is.na(GDP_USD_2018) == TRUE ~ TRUE,  
    TRUE ~ FALSE  
  )) %>%  
  filter(exclude_flag == FALSE) %>%  
  select(-exclude_flag)  
  
alldata <- joinsub %>%  
  mutate(country = factor(country)) %>%  
  mutate(country3 = factor(country3)) %>%  
  mutate(US = case_when(  
    country == "United States" ~ "US",  
    TRUE ~ "Non US")
```

```

)) %>%
mutate(color = case_when(
  country == "United States" ~ "red",
  TRUE ~ "#545454"
))

alldata <- alldata[c(1:2, 13:14, 6, 12, 3:5, 7:11)]

len <- dim(alldata)[[1]]

# write_csv(alldata, paste0("data/alldata_", lubridate::today(), ".csv")) # Uncomment to export data

```

Example code for univariate explorations:

```

SPI_hist <- ggplot(data = alldata, aes(x = SPI)) +
  geom_histogram(bins = ceiling(sqrt(len - sum(is.na(alldata$SPI))))) +
  xlab("Social Progress Index") +
  ylab("Count") +
  ggtitle("Social Progress Index Distribution")

SPIsumm <- broom::tidy(round(summary(alldata$SPI), digits = 3))
sd <- round(sd(alldata$SPI, na.rm = TRUE), digits = 3)
SPIsumm <- cbind(SPIsumm, sd)
colnames(SPIsumm) <- c("Min", "Q1", "Median", "Mean", "Q3", "Max", "NA", "SD")
SPIsumm <- SPIsumm[c(1:6, 8, 7)]
SPIsumm_grob <- tableGrob(t(SPIsumm), theme = ttheme_minimal())

grid.arrange(SPI_hist, SPIsumm_grob, nrow = 1, widths = c(0.8, 0.2))

```

Example ordered country-level plot code:

```

alldata_SPI <- alldata %>%
  filter(!is.na(SPI) == TRUE) %>%
  arrange(desc(SPI)) %>%
  select(SPI, country, US, color)

alldata_SPI_top20 <- alldata_SPI %>% head(20)
alldata_SPI_bot20 <- alldata_SPI %>% tail(20)
alldata_SPI40 <- bind_rows(alldata_SPI_top20, alldata_SPI_bot20)

colors <- alldata_SPI40$color[order(alldata_SPI40$SPI)]

SPI_country_point <- ggplot(data = alldata_SPI40, aes(x = SPI,
  y = fct_reorder(country, SPI), color = US)) +
  geom_point() +
  scale_color_manual(values = c("US" = "red", "Non US" = "#65ADC2")) +
  theme(axis.text.y = element_text(color = colors)) +
  guides(color = FALSE) +
  xlim(0, 100) +
  xlab("SPI") +
  ylab("Country") +
  ggtitle("Social Progress Index by Country, \nTop and Bottom 20 Countries")

```

Example clustering code:

```

kmdf <- function(data, x, y, z){
  kmdata <- data %>%
    select(x, y, z)
  kmdata <- return(kmdata)
}

kmdata <- kmdf(clusterdata, "country", "SPI", "logGDP")

```

```

set.seed(19811221)
km_SPI_GDP <- kmeans(kmdata[, 2:3], 4)
km_SPI_GDP_cluster <- as.factor(km_SPI_GDP$cluster)

clusterdata1 <- cbind(clusterdata, km_SPI_GDP_cluster)

km_SPI_GDP_plot <- ggplot(data = clusterdata1,
  aes(x = logGDP, y = SPI,
    color = km_SPI_GDP_cluster,
    size = US,
    shape = HDI_cat)) +

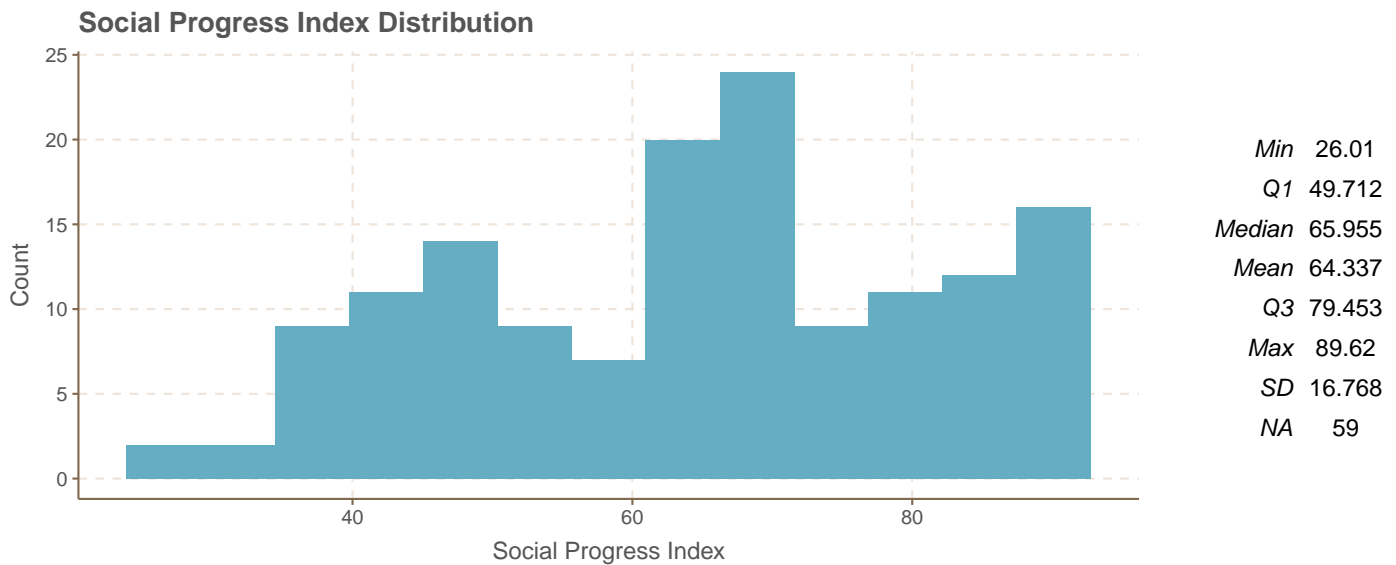
  geom_point() +
  ylim(0, 100) +
  scale_color_manual(values = wes) +
  scale_shape_manual(values = c(18, 17, 15, 16)) +
  scale_x_continuous(labels = scales::dollar_format(prefix = "$")) +
  guides(color = guide_legend(title = "Cluster"),
    size = FALSE,
    shape = guide_legend(reverse = TRUE, title = "HDI Category")) +
  xlab("log(GDP) ($US 2018)") +
  ylab("Social Progress Index") +
  ggtitle("Cluster Analysis, Social Progress Index vs. GDP")
km_SPI_GDP_plot

```

## Results

### Data Exploration and Visualizations

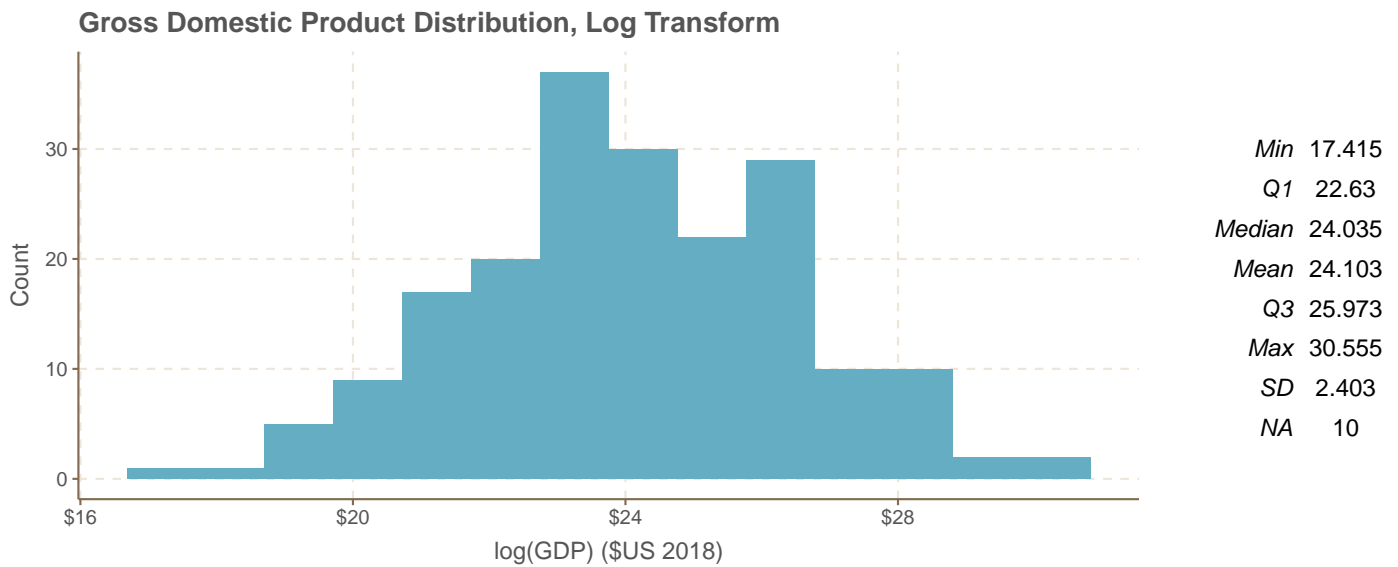
First, exploring the Social Progress Index data:



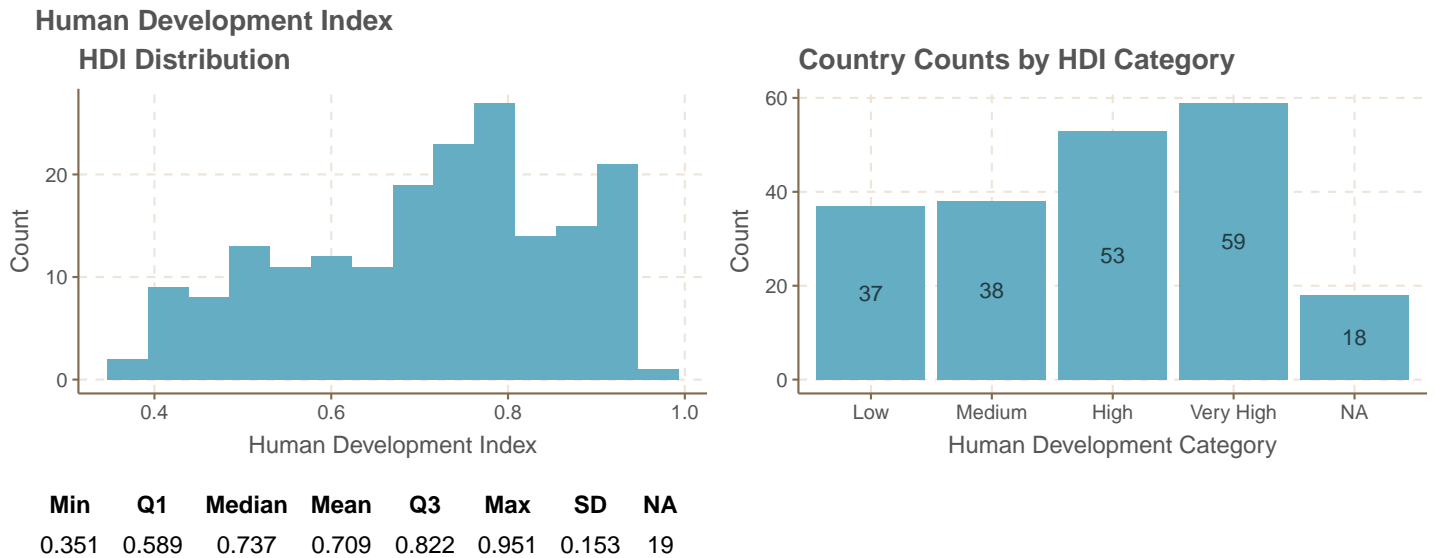
Next, exploring GDP by summary statistics:

Min	Q1	Median	Mean	Q3	Max	SD	NA
36572612	6734069913	27424071373	383069641832	1.90463e+11	1.86245e+13	1.640295e+12	10

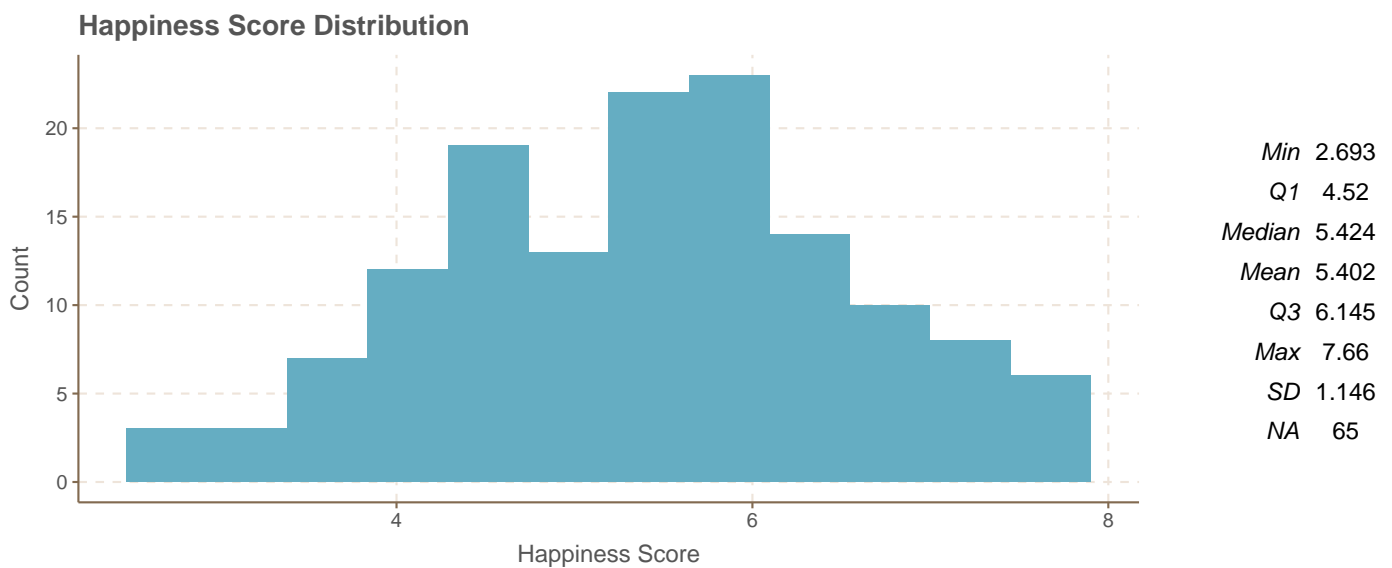
Taking the log transform and plotting:



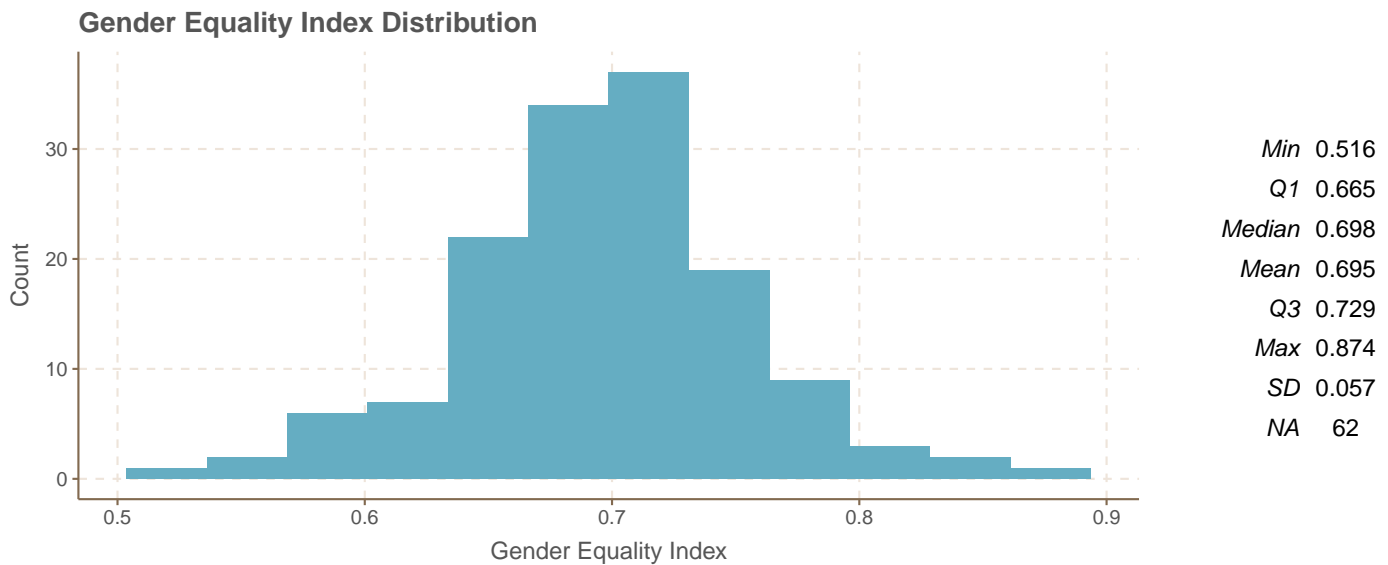
Exploring the Human Development Index variables:



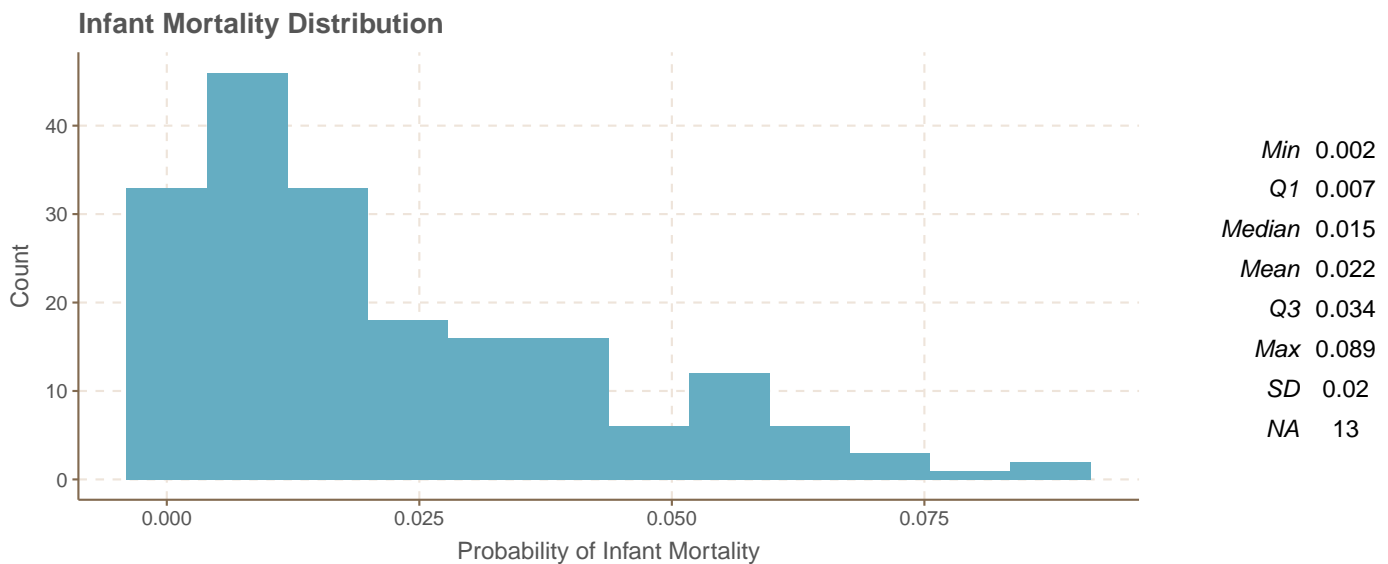
Exploring the World Happiness Report data:



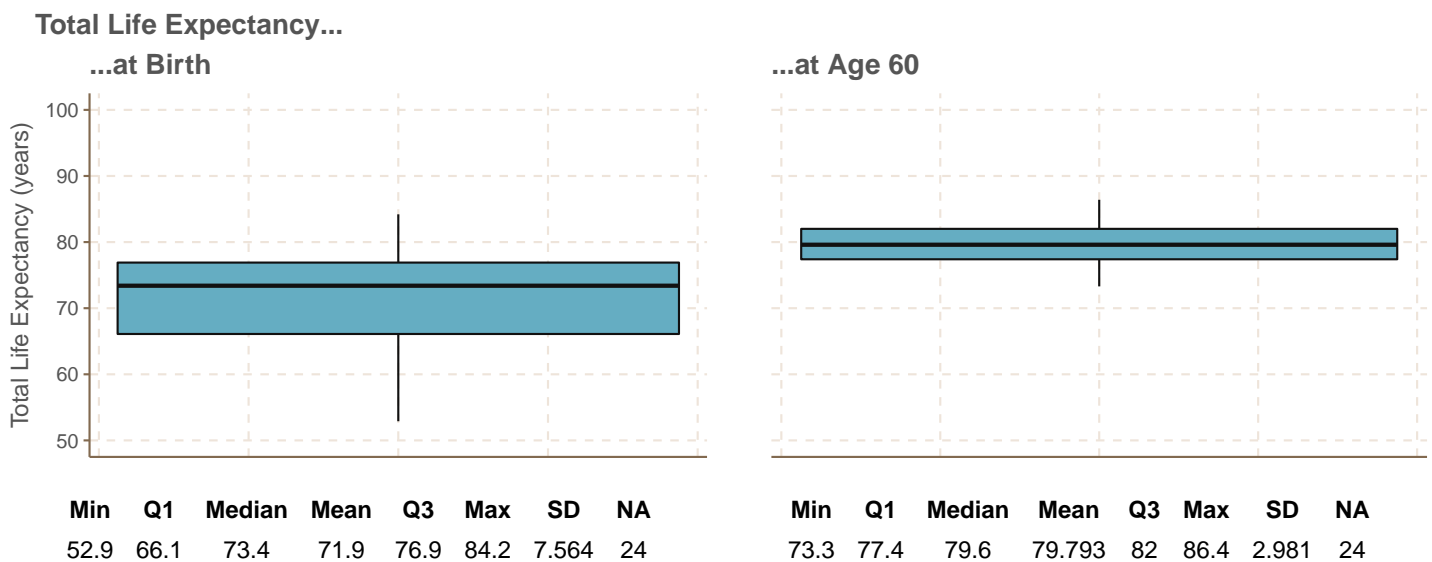
Exploring the gender equality index data:



Exploring the WHO infant mortality rate data:



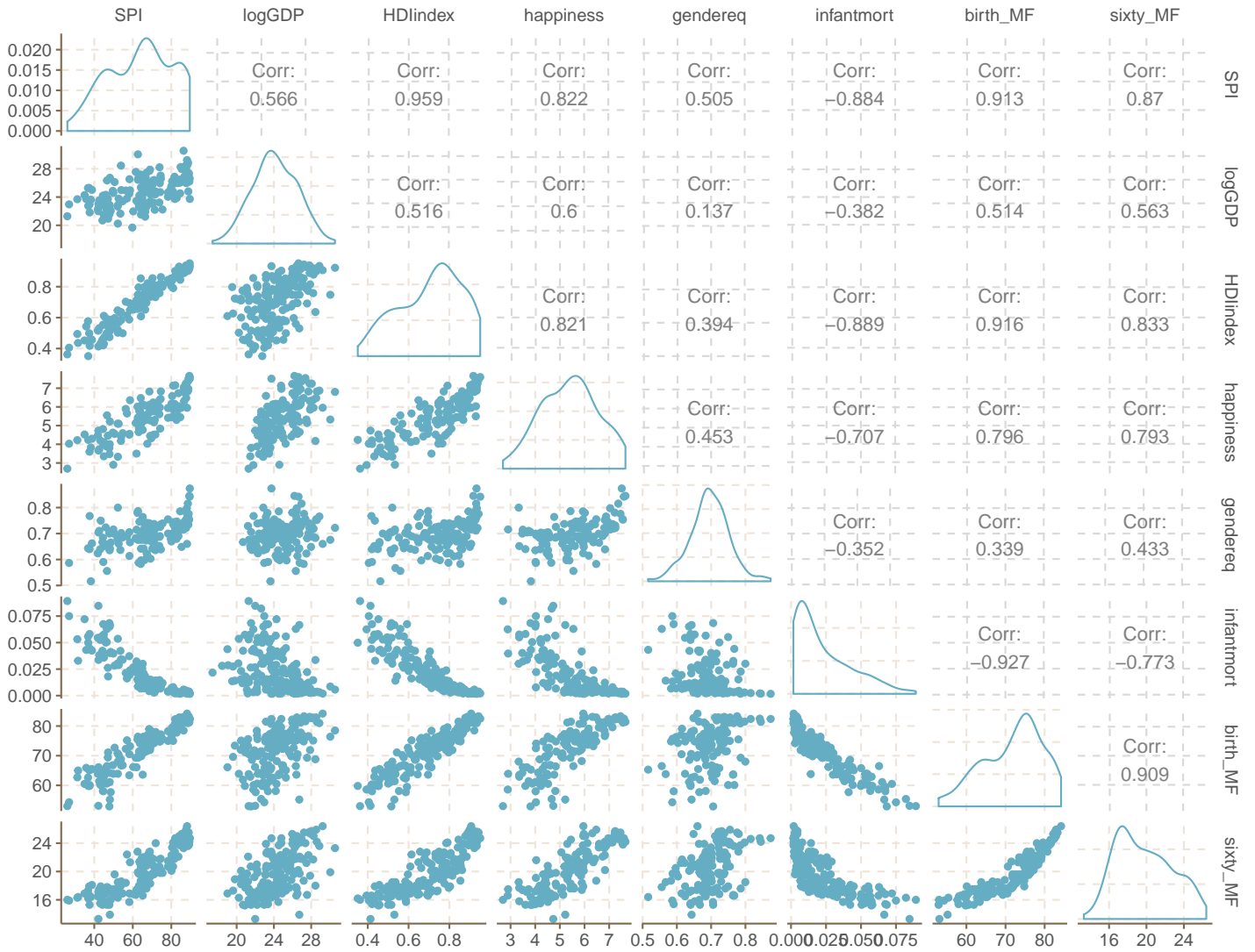
Exploring the WHO life expectancy data:



Investigating pairwise relationships between continuous variables:



## Correlation Matrix, Continuous Variables



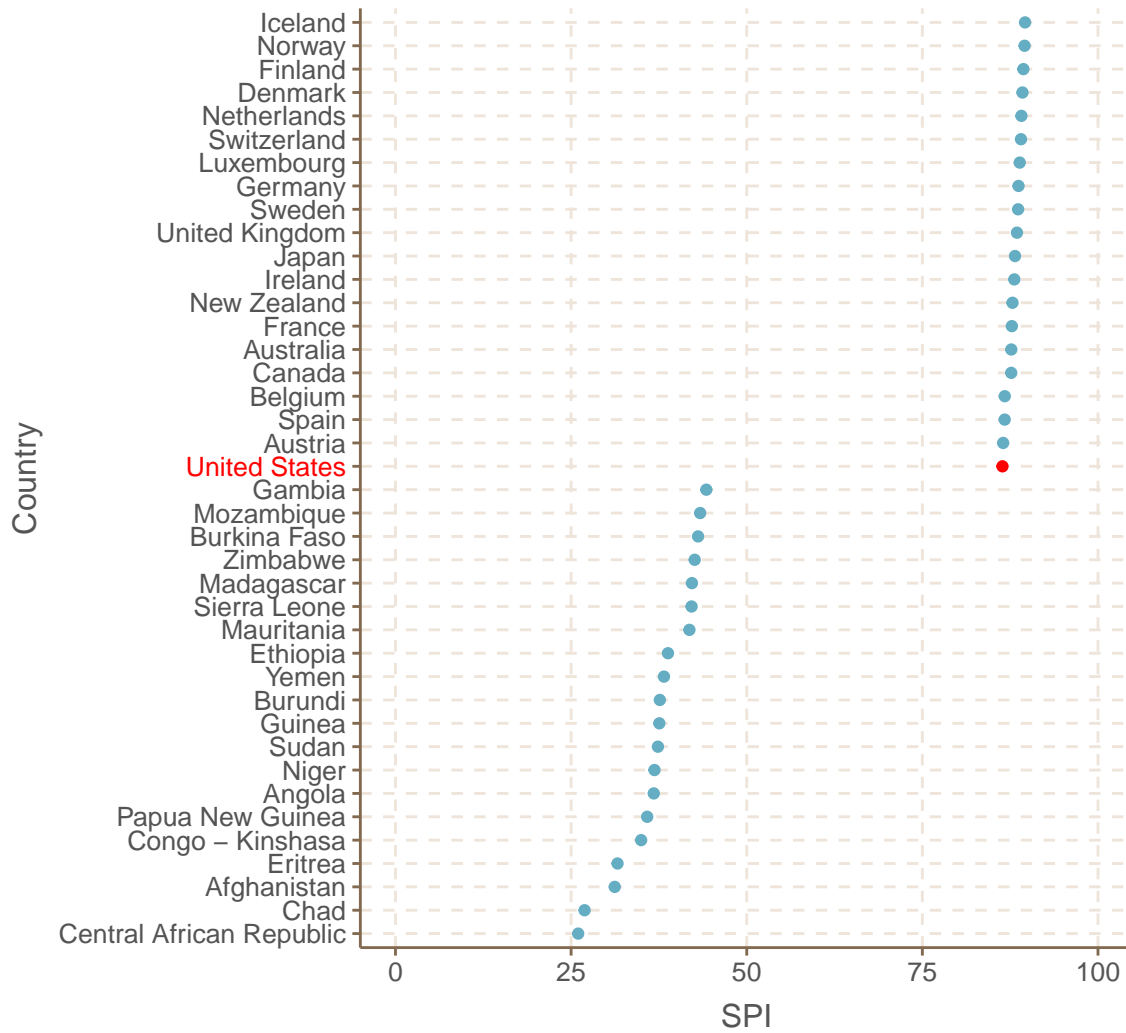
Strong positive linear relationships are seen between HDIindex and SPI, happiness, and birth\_MF; between SPI and happiness, birth\_MF, and sixty\_MF; and between happiness and sixty\_MF. Additionally, strong positive relationships that are possibly nonlinear are seen between HDIindex and sixty\_MF, and between birth\_MF and sixty\_MF.

Strong negative relationships are seen between infantmort and birth\_MF, between HDIindex and infantmort, and between SPI and infantmort, though the latter two of these may not necessarily be linear. A strong negative nonlinear relationship is seen between infantmort and sixty\_MF.

Since the goal of this analysis is to compare countries with particular focus on the United States, factor-ordered bivariate plots were generated to explore how the countries compare across the variables of interest, with the United States denoted in red.

First, the top and bottom 20 countries were compared by Social Progress Index:

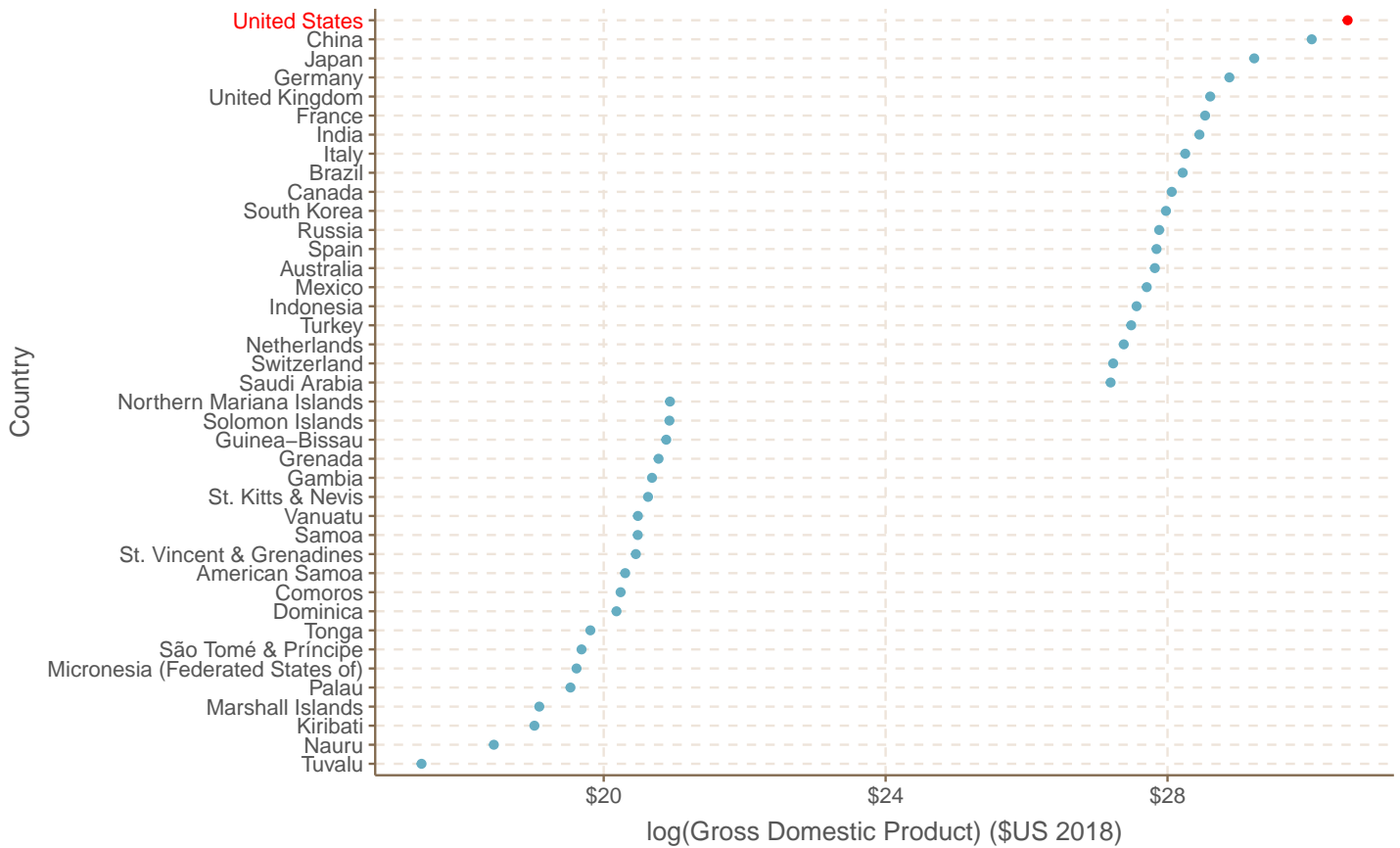
## Social Progress Index by Country, Top and Bottom 20 Countries



The United States ranks twentieth in social progress.

Next, exploring GDP by country:

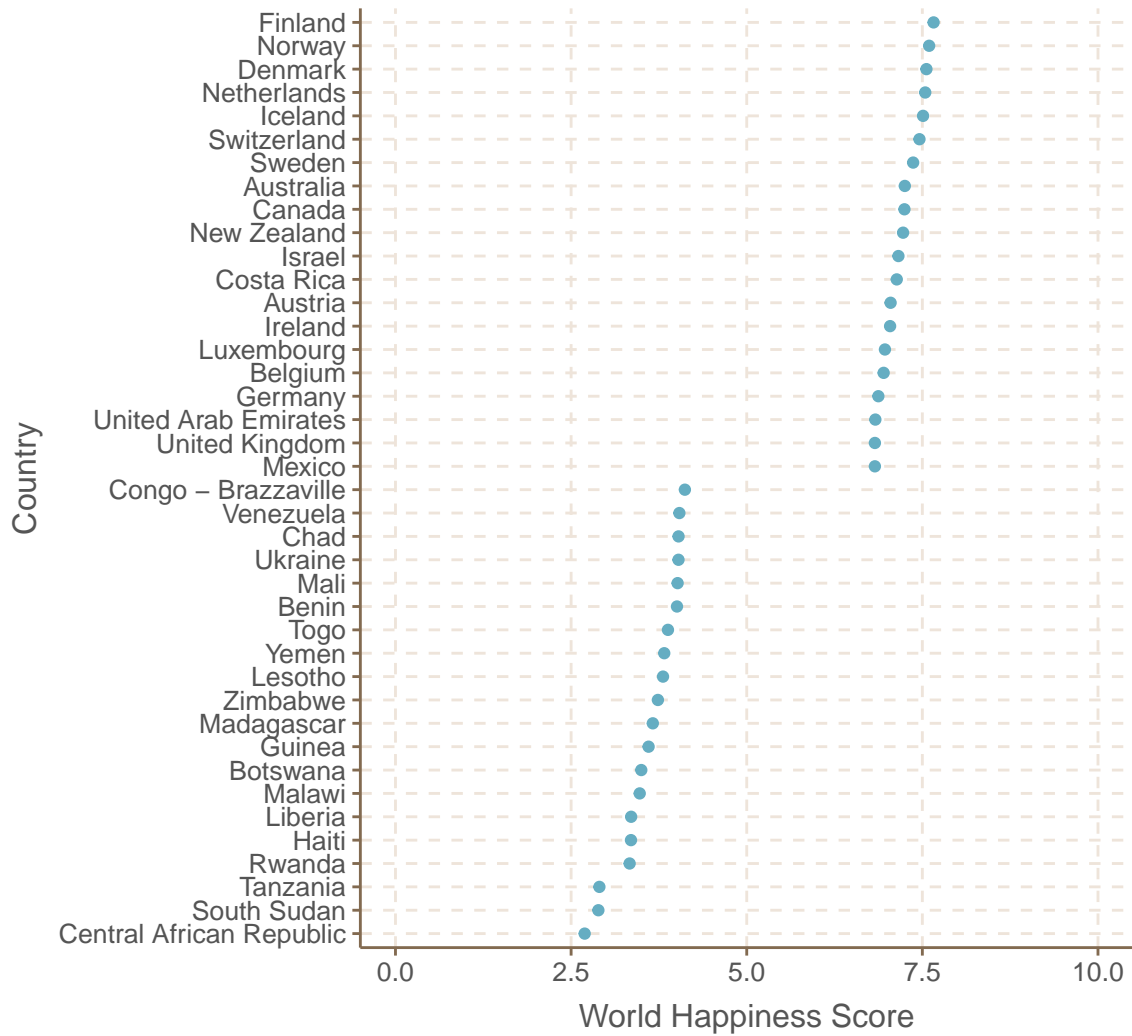
## Gross Domestic Product by Country, Log Scale, Top and Bottom 20 Countries



The United States has the world's largest GDP.

Next, World Happiness Score:

## World Happiness Score by Country, Top and Bottom 20 Countries



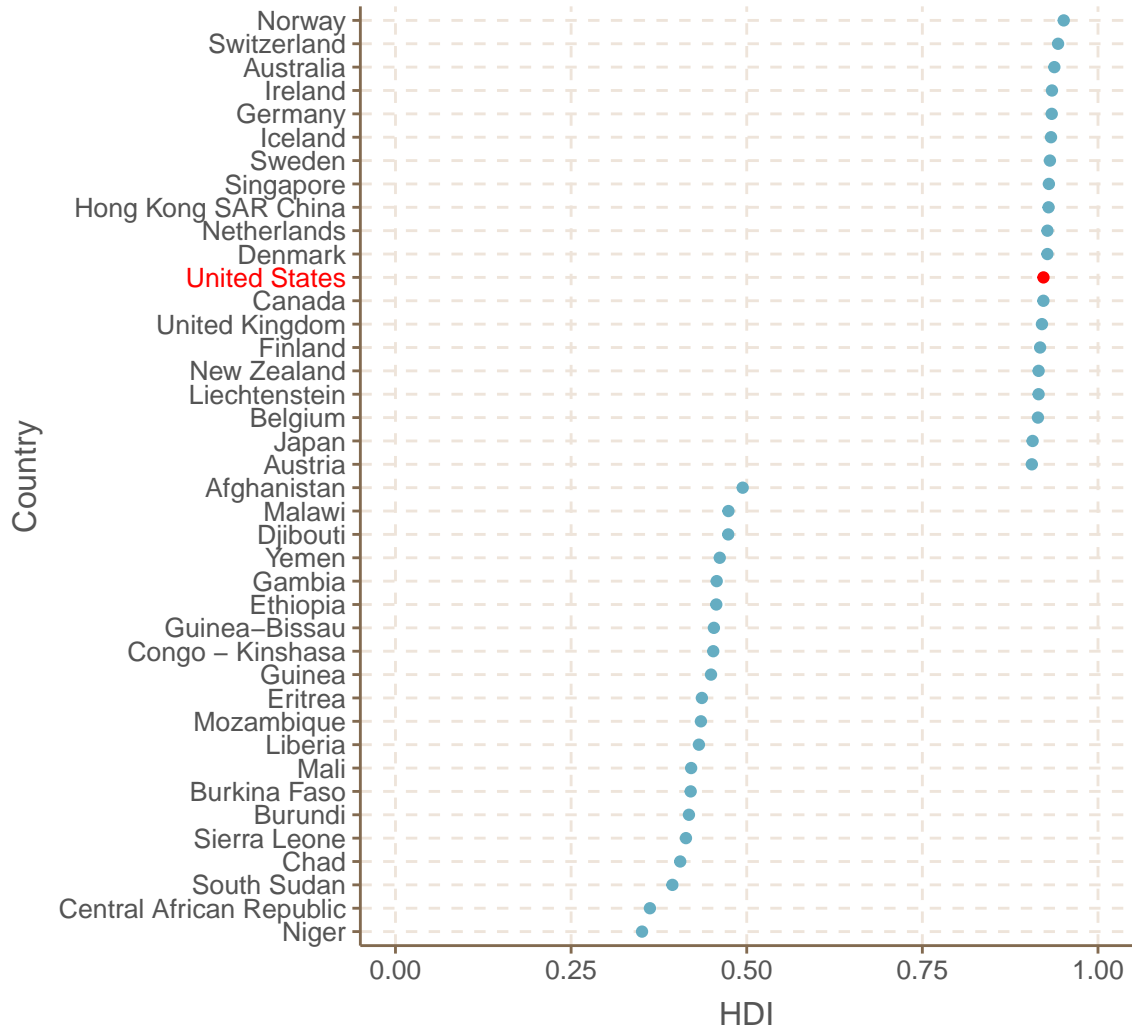
```
which(alldata_WHR$country == "United States")
```

```
## [1] 21
```

The United States is not among the top 20 countries in terms of happiness; it ranks 21st.

Next, the Human Development Index:

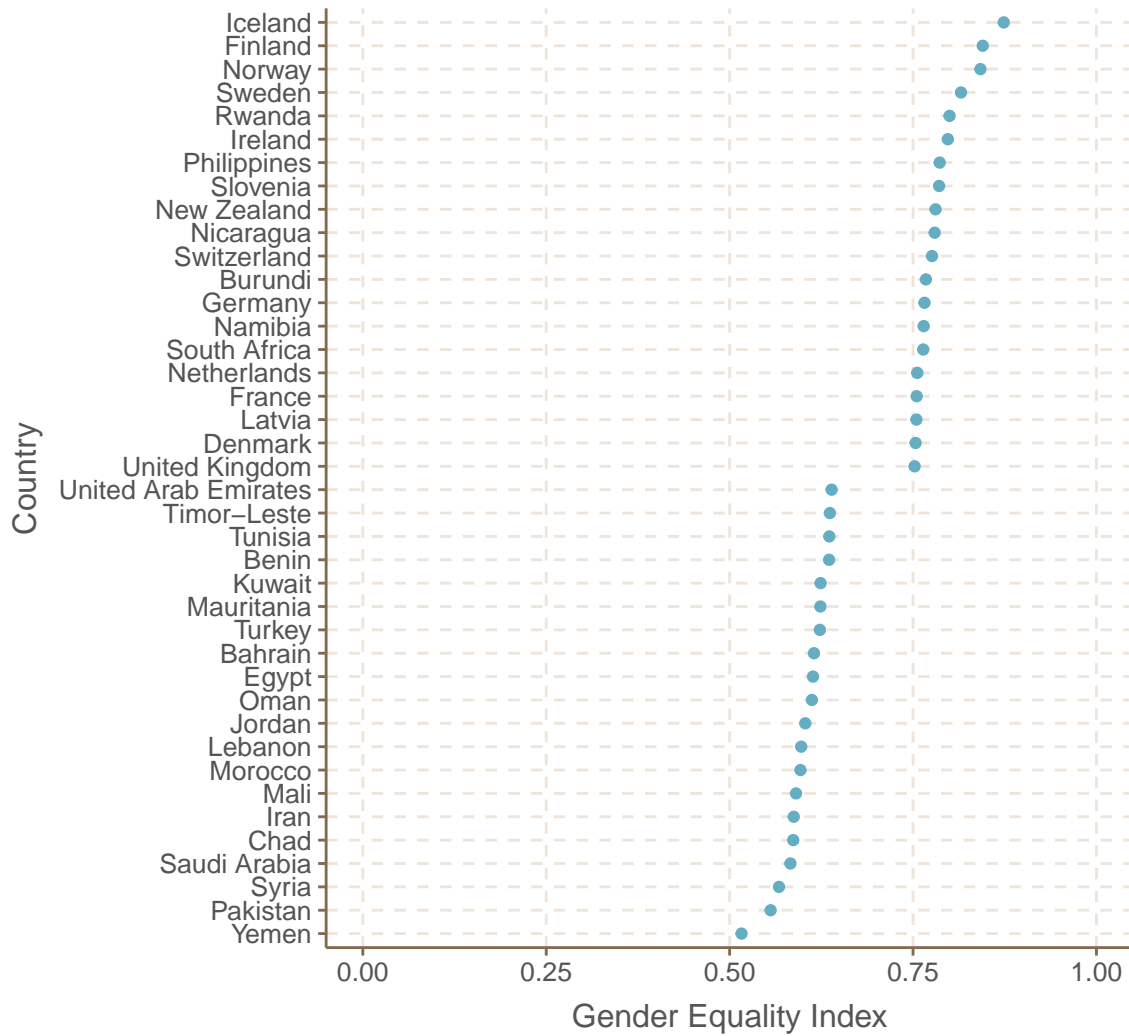
## Human Development Index by Country, Top and Bottom 20 Countries



The United States ranks twelfth by HDI.

Exploring gender equality:

## Gender Equality Index by Country, Top and Bottom 20 Countries



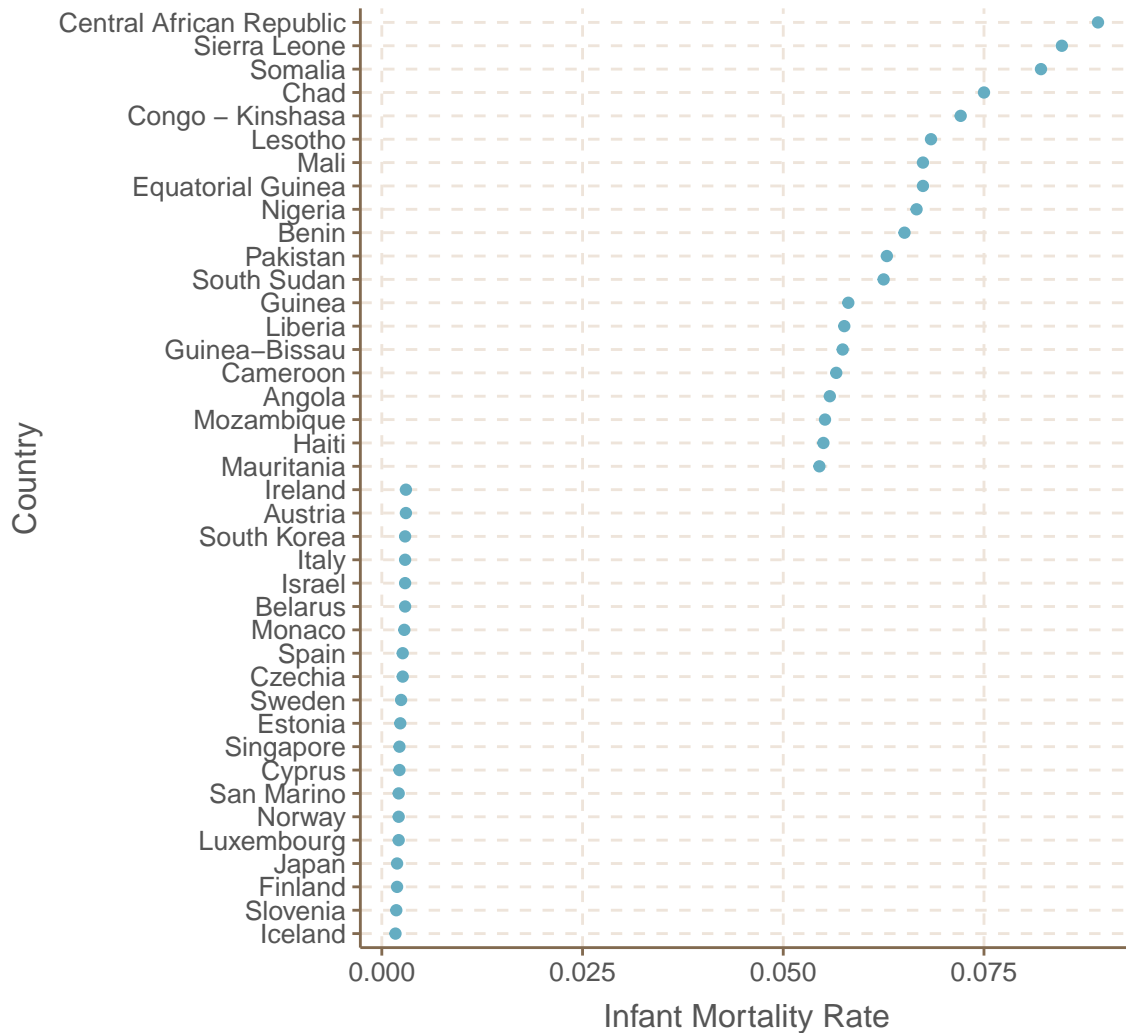
```
which(alldata_gender$country == "United States")
```

```
## [1] 45
```

The United States is not among the top 20 countries in terms of gender equality; it ranks 45th.

Examining infant mortality:

## Infant Mortality Rate, Top and Bottom 20 Countries



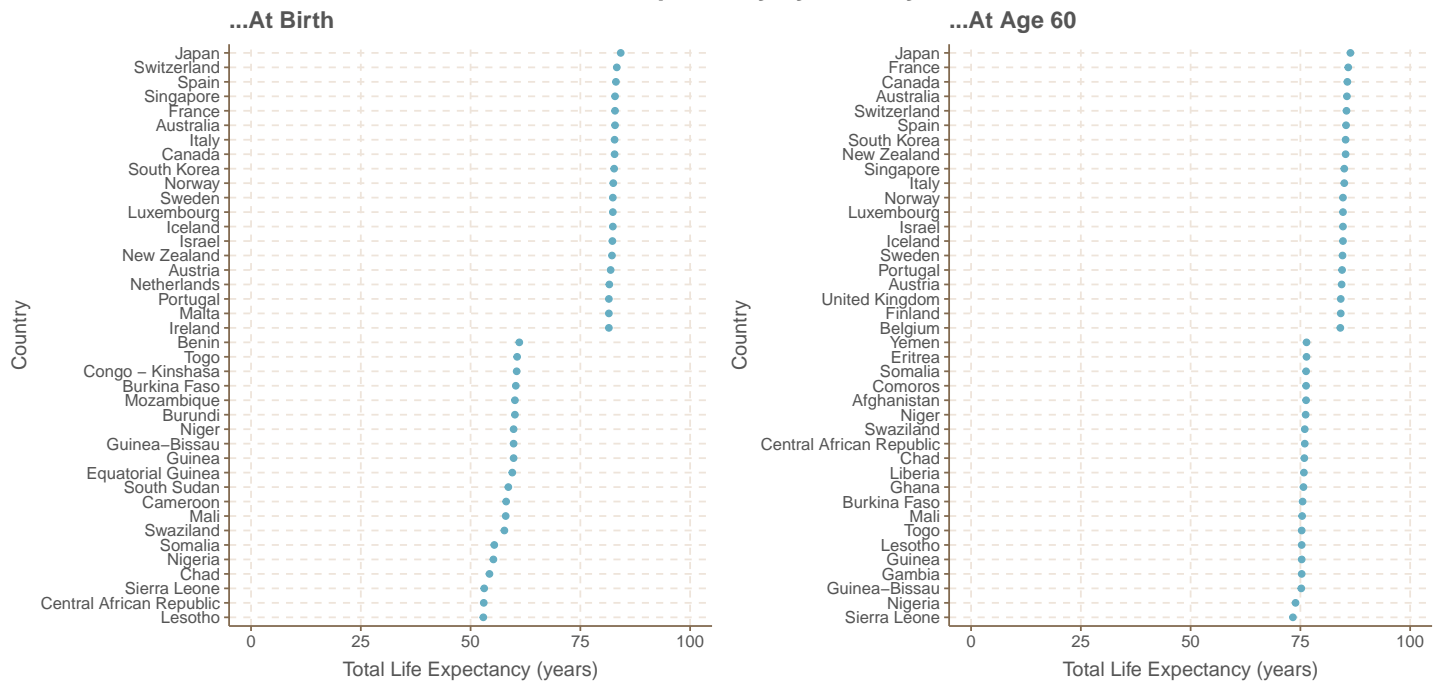
```
alldata_infantmort_asc <- alldata_infantmort %>% arrange(infantmort)
which(alldata_infantmort_asc$country == "United States")
```

```
## [1] 46
```

The United States has the world's 46th lowest infant mortality rate.

Finally, exploring life expectancy:

## Total Life Expectancy by Country...



```
which(alldata_lifeexp_birth$country == "United States")
```

```
## [1] 34
```

```
which(alldata_lifeexp_sixty$country == "United States")
```

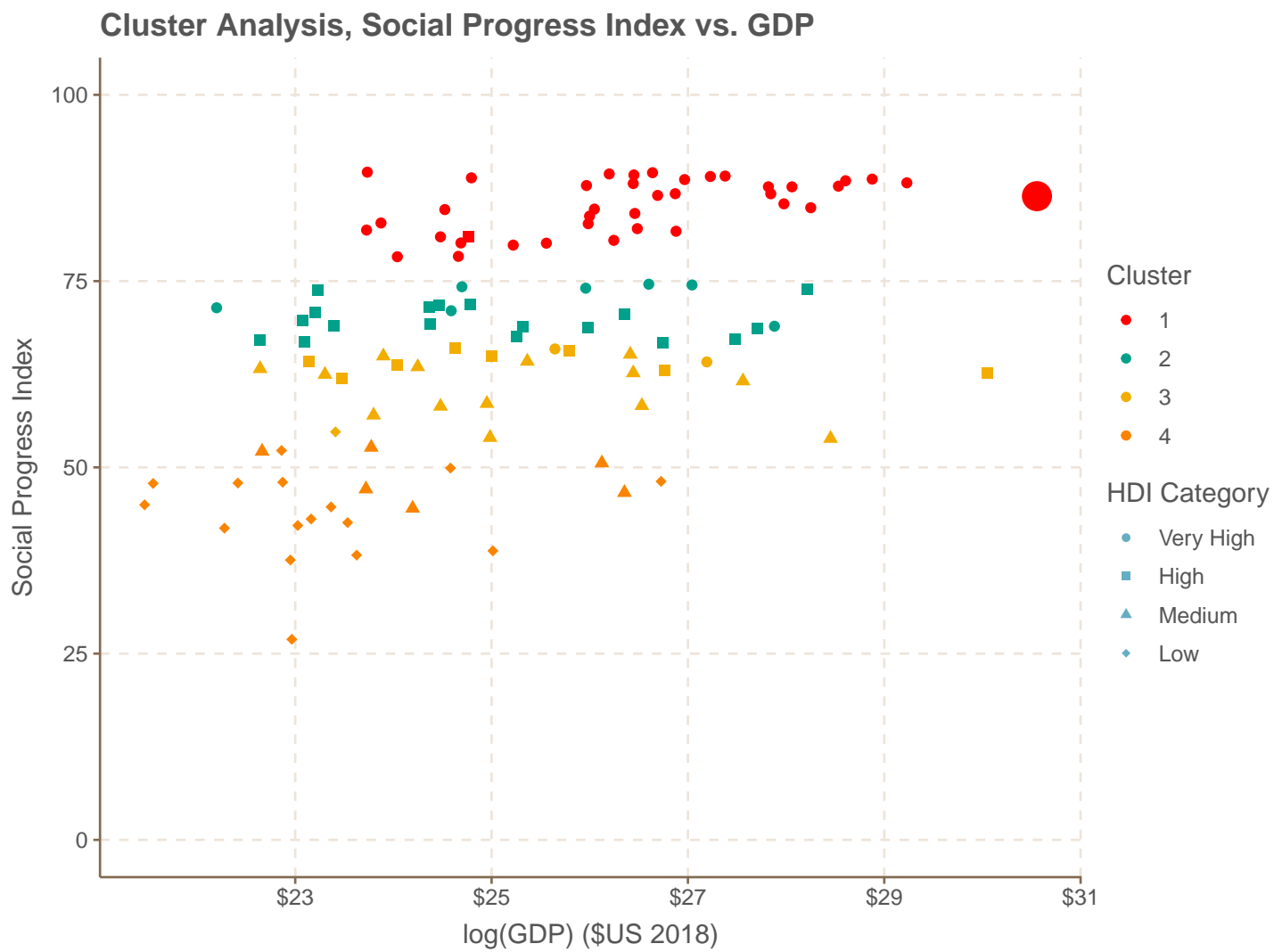
```
## [1] 31
```

Once again, the United States is not among the top 20 countries for life expectancy, ranking 34th and 31st respectively for life expectancy at birth and at 60 years of age.

## Clustering Analysis

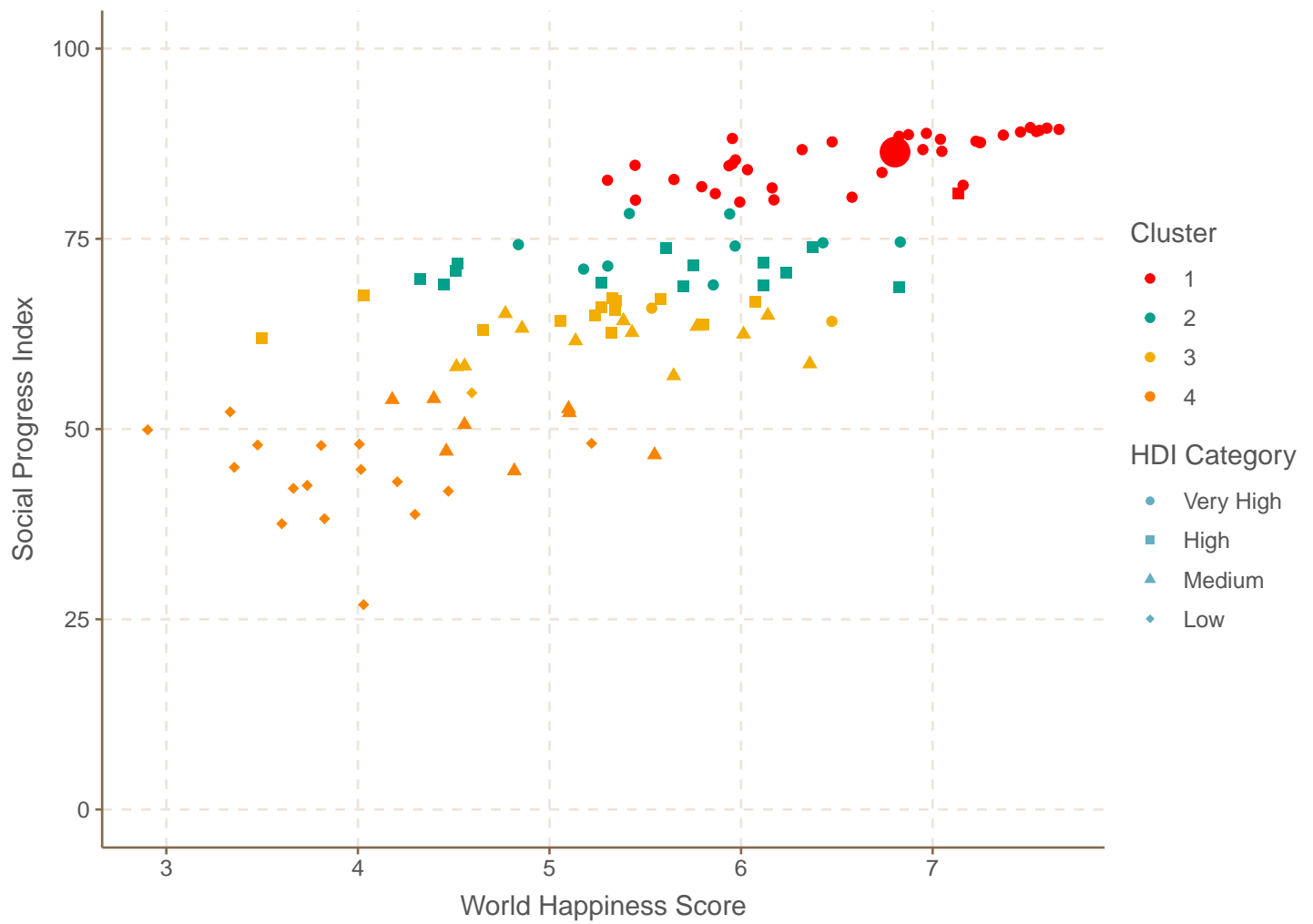
Clustering social progress versus log GDP:





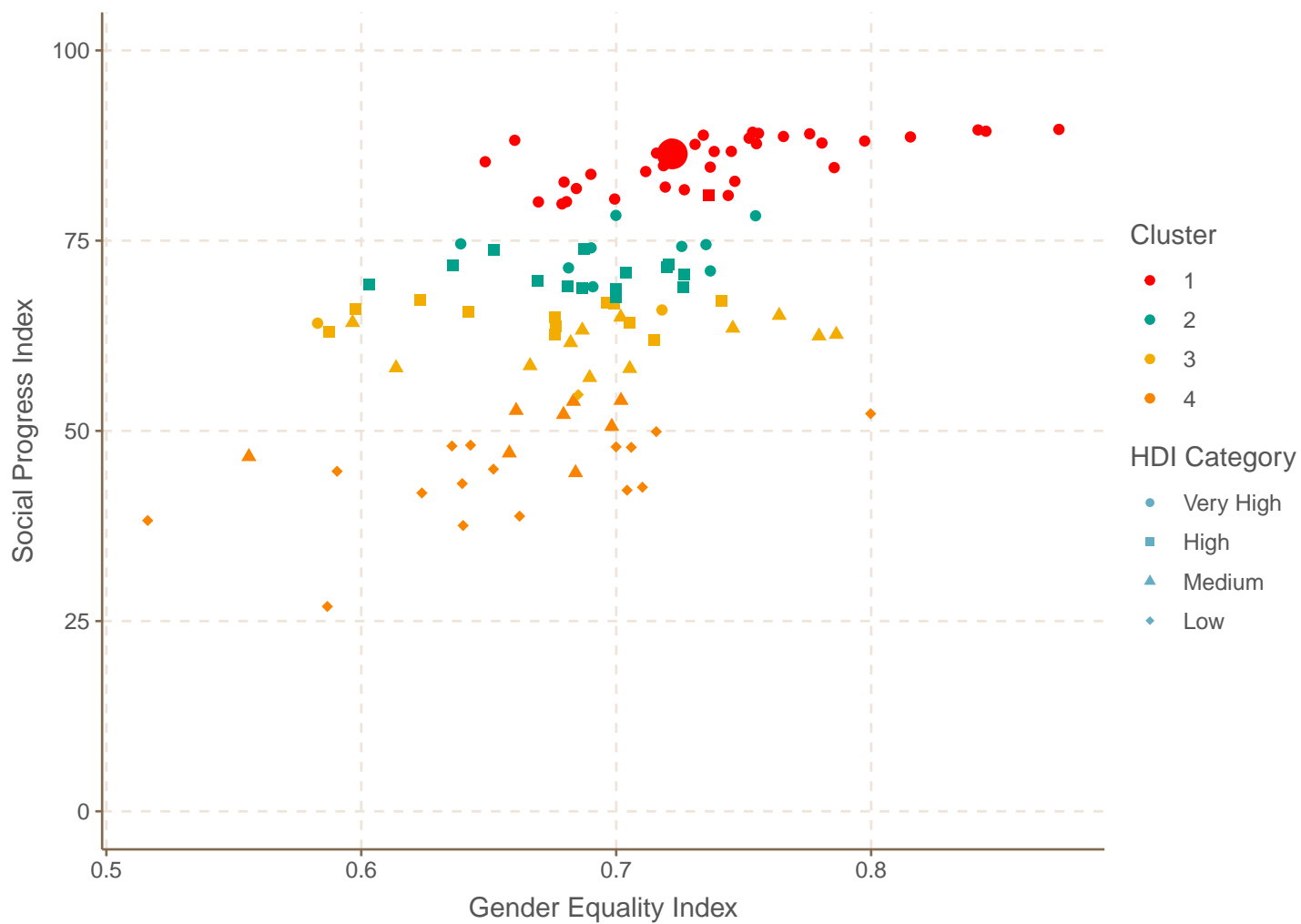
Clustering social progress versus happiness:

## Cluster Analysis, Social Progress Index vs. World Happiness Score



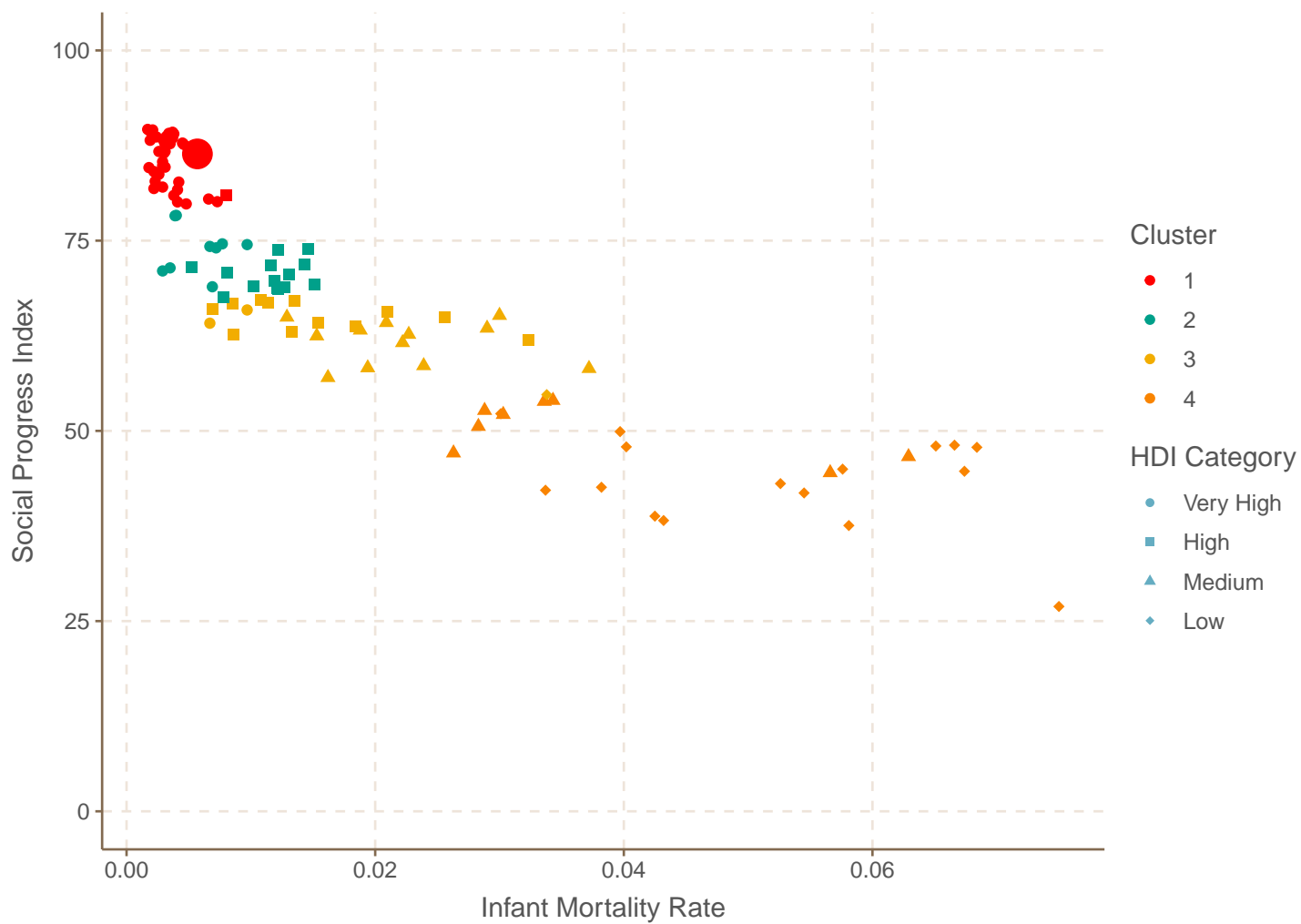
Clustering social progress versus gender equality:

## Cluster Analysis, Social Progress Index vs. Gender Equality Index



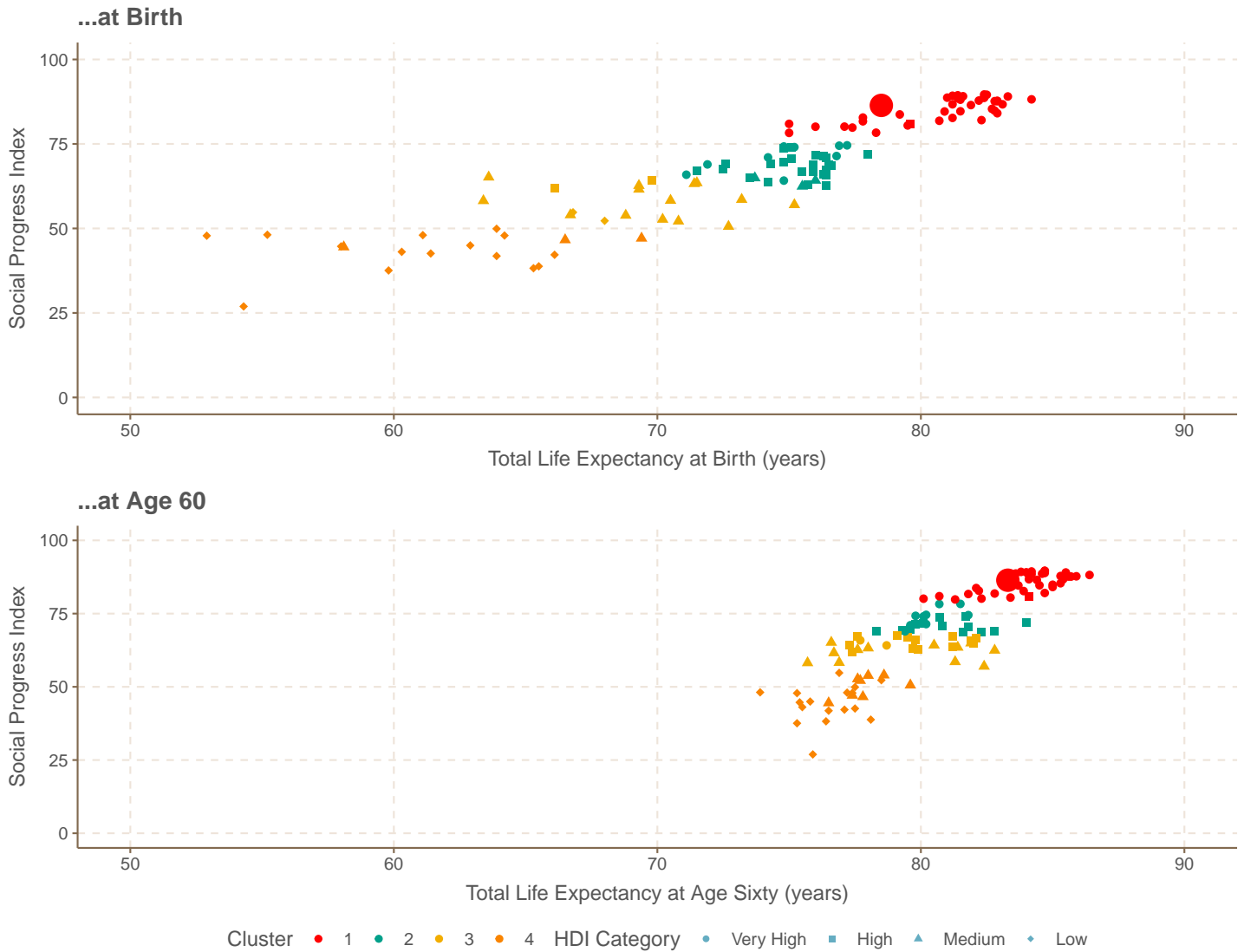
Clustering social progress versus infant mortality:

Cluster Analysis, Social Progress Index vs. Infant Mortality Rate



Clustering social progress versus life expectancy:

## Cluster Analysis, Social Progress Index vs. Total Life Expectancy...



## Discussion

### Limitations

### Conclusion

### References

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high\_desc=true.

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World Health Organization. 2018a. “Life Expectancy.” <http://apps.who.int/gho/data/view.main.SDG2016LEXv?lang=en>.

———. 2018b. “Probability of Dying Per 1000 Live Births.” <http://apps.who.int/gho/data/view.main.182?lang=en>.