Life Expectancy Analysis

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Life expectancy is a statistical measure of the average time someone is expected to live, based on the year of their birth, current age and other demographic factors including their sex. Period life expectancy assumes mortality rates remain constant into the future, while cohort life expectancy uses projected changes in future mortality rates. Period life expectancy (ex) is the average number of additional years a person would live if he or she experienced the age-specific mortality rates of the given area and time period for the rest of their life.

```
library(dplyr)

##
## Attaching package: 'dplyr'

## The following objects are masked from 'package:stats':
##
##     filter, lag

## The following objects are masked from 'package:base':
##
##     intersect, setdiff, setequal, union

library(tidyverse)

## ── Attaching packages
## ───────────────────────────────────────
## tidyverse 1.3.2 ──

## ✔ ggplot2 3.3.6     ✔ purrr   0.3.5
## ✔ tibble  3.1.8     ✔ stringr 1.4.1
## ✔ tidyr   1.2.1     ✔ forcats 0.5.2
## ✔ readr   2.1.3
## ── Conflicts ──────────────────────────────────────────
tidyverse_conflicts() ──
## ✖ dplyr::filter() masks stats::filter()
## ✖ dplyr::lag()    masks stats::lag()

library(ggplot2)
```

Loaded and cleaned the data–removed all cases with missing life expectancy, year, country name and code.

```
data=read.delim("gapminder.csv.bz2")
ncol(data)

## [1] 25

nrow(data)

## [1] 13055

#renaming time to year
data=data %>%rename(year=time)
head(data)

##   iso3  name iso2   region                      sub.region
intermediate.region
## 1  ABW Aruba   AW Americas Latin America and the Caribbean
Caribbean
## 2  ABW Aruba   AW Americas Latin America and the Caribbean
Caribbean
## 3  ABW Aruba   AW Americas Latin America and the Caribbean
Caribbean
## 4  ABW Aruba   AW Americas Latin America and the Caribbean
Caribbean
## 5  ABW Aruba   AW Americas Latin America and the Caribbean
Caribbean
## 6  ABW Aruba   AW Americas Latin America and the Caribbean
Caribbean
##   year totalPopulation fertilityRate lifeExpectancy childMortality
## 1 1960           54211         4.820         65.662             NA
## 2 1961           55438         4.655         66.074             NA
## 3 1962           56225         4.471         66.444             NA
## 4 1963           56695         4.271         66.787             NA
## 5 1964           57032         4.059         67.113             NA
## 6 1965           57360         3.842         67.435             NA
##   youthFemaleLiteracy youthMaleLiteracy adultLiteracy GDP_PC
accessElectricity
## 1                  NA                NA            NA     NA
NA
## 2                  NA                NA            NA     NA
NA
## 3                  NA                NA            NA     NA
NA
## 4                  NA                NA            NA     NA
NA
## 5                  NA                NA            NA     NA
NA
## 6                  NA                NA            NA     NA
NA
##   agriculturalLand agricultureTractors cerealProduction fertilizerHa
co2
## 1               NA                  NA               NA           NA
```

```
11092.67
## 2               20                  NA               NA           NA
11576.72
## 3               20                  NA               NA           NA
12713.49
## 4               20                  NA               NA           NA
12178.11
## 5               20                  NA               NA           NA
11840.74
## 6               20                  NA               NA           NA
10623.30
##   greenhouseGases   co2_PC pm2.5_35 battleDeaths
## 1              NA 204.6204       NA           NA
## 2              NA 208.8228       NA           NA
## 3              NA 226.1181       NA           NA
## 4              NA 214.8004       NA           NA
## 5              NA 207.6158       NA           NA
## 6              NA 185.2040       NA           NA
```

```
#checking nulls
sum(is.na(data$lifeExpectancy))

## [1] 1325

sum(is.na(data$year))

## [1] 36

sum(is.na(data$name))

## [1] 0

sum(is.na(data$iso3))

## [1] 0

sum(is.na(data$iso2))

## [1] 0

#removing nulls and blanks
data = data[!(is.na(data$lifeExpectancy) | data$lifeExpectancy==""), ]
data = data[!(is.na(data$year) | data$year==""), ]
data = data[!(data$name==""), ]
data = data[!(data$iso3==""), ]
data = data[!(data$iso2==""), ]
ncol(data)

## [1] 25

nrow(data)

## [1] 11558
```

There are 203 unique countries in our data

```
length(unique(data$name))

## [1] 203
```

The first and last year with valid life expectancy data

```
first = min(data$year)
firstRow=data[which.min(data$year),]
firstRow

##   iso3  name iso2   region                      sub.region
intermediate.region
## 1  ABW Aruba   AW Americas Latin America and the Caribbean
Caribbean
##   year totalPopulation fertilityRate lifeExpectancy childMortality
## 1 1960           54211          4.82         65.662             NA
##   youthFemaleLiteracy youthMaleLiteracy adultLiteracy GDP_PC
accessElectricity
## 1                  NA                NA            NA     NA
NA
##   agriculturalLand agricultureTractors cerealProduction fertilizerHa
co2
## 1               NA                  NA               NA           NA
11092.67
##   greenhouseGases   co2_PC pm2.5_35 battleDeaths
## 1              NA 204.6204       NA           NA

last = max(data$year)
lastRow=data[which.max(data$year),]
lastRow

##    iso3  name iso2   region                      sub.region
intermediate.region
## 60  ABW Aruba   AW Americas Latin America and the Caribbean
Caribbean
##    year totalPopulation fertilityRate lifeExpectancy childMortality
## 60 2019          106314         1.901         76.293             NA
##    youthFemaleLiteracy youthMaleLiteracy adultLiteracy GDP_PC
accessElectricity
## 60                  NA                NA            NA     NA
100
##    agriculturalLand agricultureTractors cerealProduction fertilizerHa co2
## 60               NA                  NA               NA           NA  NA
##    greenhouseGases co2_PC pm2.5_35 battleDeaths
## 60              NA     NA       NA           NA

cat("first year with valid life expectancy", first,"\n")

## first year with valid life expectancy 1960
```

```
cat("last year with valid life expectancy ", last,"\n")

## last year with valid life expectancy  2019
```

Lowest and highest life expectancy values and the country/year they correspond to

The lowest life expectancy wass present in Cambodia (1977) The highest life expectancy was present in San Marino (2012)

```
min=data[which.min(data$lifeExpectancy),]
min

##      iso3     name iso2 region         sub.region intermediate.region year
## 6098  KHM Cambodia   KH   Asia South-eastern Asia                     1977
##      totalPopulation fertilityRate lifeExpectancy childMortality
## 6098         7196042         5.557         18.907          260.2
##      youthFemaleLiteracy youthMaleLiteracy adultLiteracy GDP_PC
## 6098                  NA                NA            NA     NA
##      accessElectricity agriculturalLand agricultureTractors
cerealProduction
## 6098                NA            25500                1233
1080000
##      fertilizerHa   co2 greenhouseGases  co2_PC pm2.5_35 battleDeaths
## 6098           NA 73.34        11996.91 0.01019       NA           NA

max=data[which.max(data$lifeExpectancy),]
max

##       iso3       name iso2 region      sub.region intermediate.region year
## 10582  SMR San Marino   SM Europe Southern Europe                     2012
##       totalPopulation fertilityRate lifeExpectancy childMortality
## 10582           32105          1.26       85.41707            2.4
##       youthFemaleLiteracy youthMaleLiteracy adultLiteracy   GDP_PC
## 10582                  NA                NA            NA 49939.01
##       accessElectricity agriculturalLand agricultureTractors
cerealProduction
## 10582               100               10                  NA
NA
##       fertilizerHa co2 greenhouseGases co2_PC pm2.5_35 battleDeaths
## 10582           NA  NA              NA     NA       NA           NA
```

The shortest life expectancy corresponds to a genocide in Cambodia which resulted in the death of 1.5 to 2 million people during 1975 to 1979

Plotting the life expectancy over time for all countries.

I added Rwanda because there was a genocide in 1994 which resulted in deaths of 800,000 people.

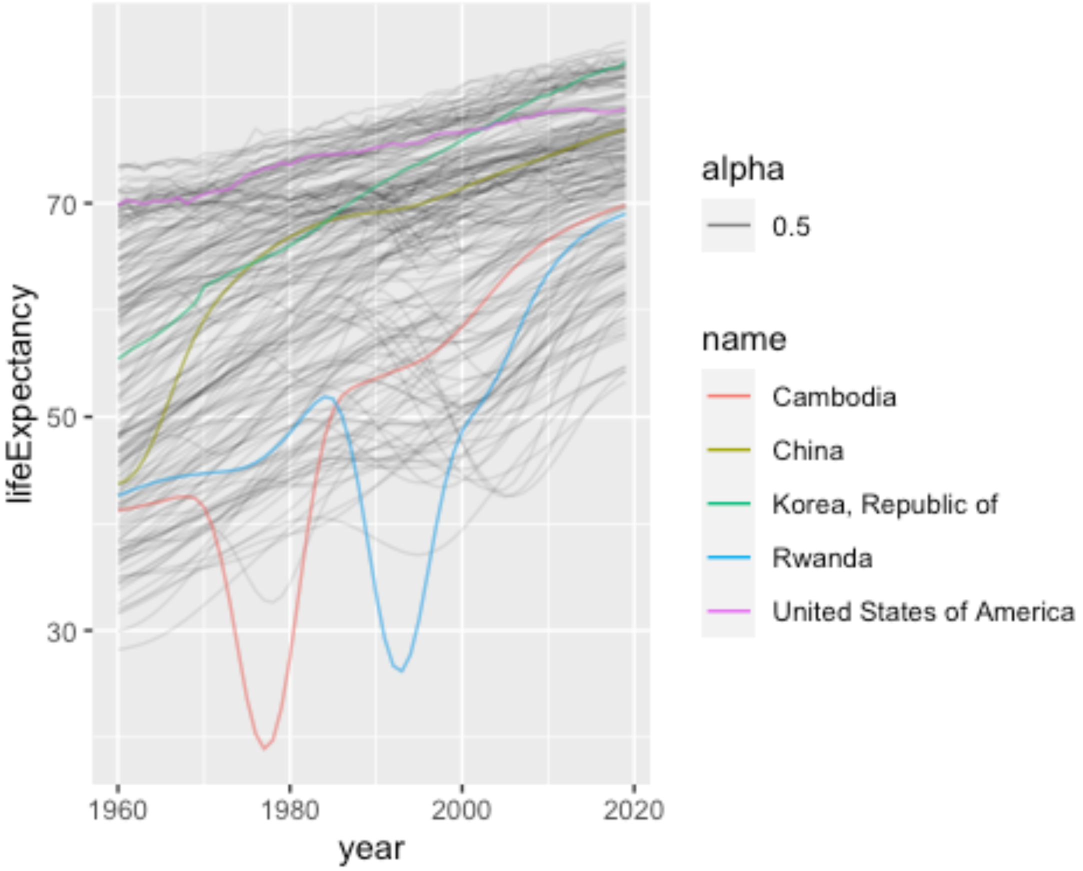
```
p <- ggplot(data=data, aes(x=year, y=lifeExpectancy, group=name,
fill="gray")) +
    geom_line(alpha=0.1)
```

```
data_subset=data%>%filter(name=="United States of America"|name=="Korea,
Republic of"|name=="Cambodia"|name=="China"|name=="Rwanda")
head(data_subset)
```

```
##   iso3  name iso2 region   sub.region intermediate.region year
totalPopulation
## 1  CHN China   CN   Asia Eastern Asia                     1960
667070000
## 2  CHN China   CN   Asia Eastern Asia                     1961
660330000
## 3  CHN China   CN   Asia Eastern Asia                     1962
665770000
## 4  CHN China   CN   Asia Eastern Asia                     1963
682335000
## 5  CHN China   CN   Asia Eastern Asia                     1964
698355000
## 6  CHN China   CN   Asia Eastern Asia                     1965
715185000
##   fertilityRate lifeExpectancy childMortality youthFemaleLiteracy
## 1         5.756         43.725             NA                  NA
## 2         5.905         44.051             NA                  NA
## 3         6.062         44.783             NA                  NA
## 4         6.206         45.972             NA                  NA
## 5         6.320         47.592             NA                  NA
## 6         6.385         49.549             NA                  NA
##   youthMaleLiteracy adultLiteracy   GDP_PC accessElectricity
agriculturalLand
## 1                NA            NA 191.9572                NA
NA
## 2                NA            NA 141.0355                NA
3432480
## 3                NA            NA 132.0776                NA
3460010
## 4                NA            NA 142.1449                NA
3488540
## 5                NA            NA 164.1333                NA
3517060
## 6                NA            NA 187.4367                NA
3555090
##   agricultureTractors cerealProduction fertilizerHa      co2
greenhouseGases
## 1                  NA               NA           NA 780726.3
NA
## 2               52661        109659976      7.04082 552066.8
NA
## 3               55360        120421293      9.59845 440359.0
NA
## 4               59657        137456233     12.11821 436695.7
NA
## 5               66290        152356625     16.32832 436923.0
```

```
NA
## 6               73021        162156281     25.41529 475972.9
NA
##    co2_PC pm2.5_35 battleDeaths
## 1 1.17038       NA           NA
## 2 0.83605       NA           NA
## 3 0.66143       NA           NA
## 4 0.64000       NA           NA
## 5 0.62565       NA           NA
## 6 0.66552       NA           NA
```

```
p=p+geom_line(data=data_subset, aes(x=year, y=lifeExpectancy,group=name,
color=name, alpha=0.5))
p
```

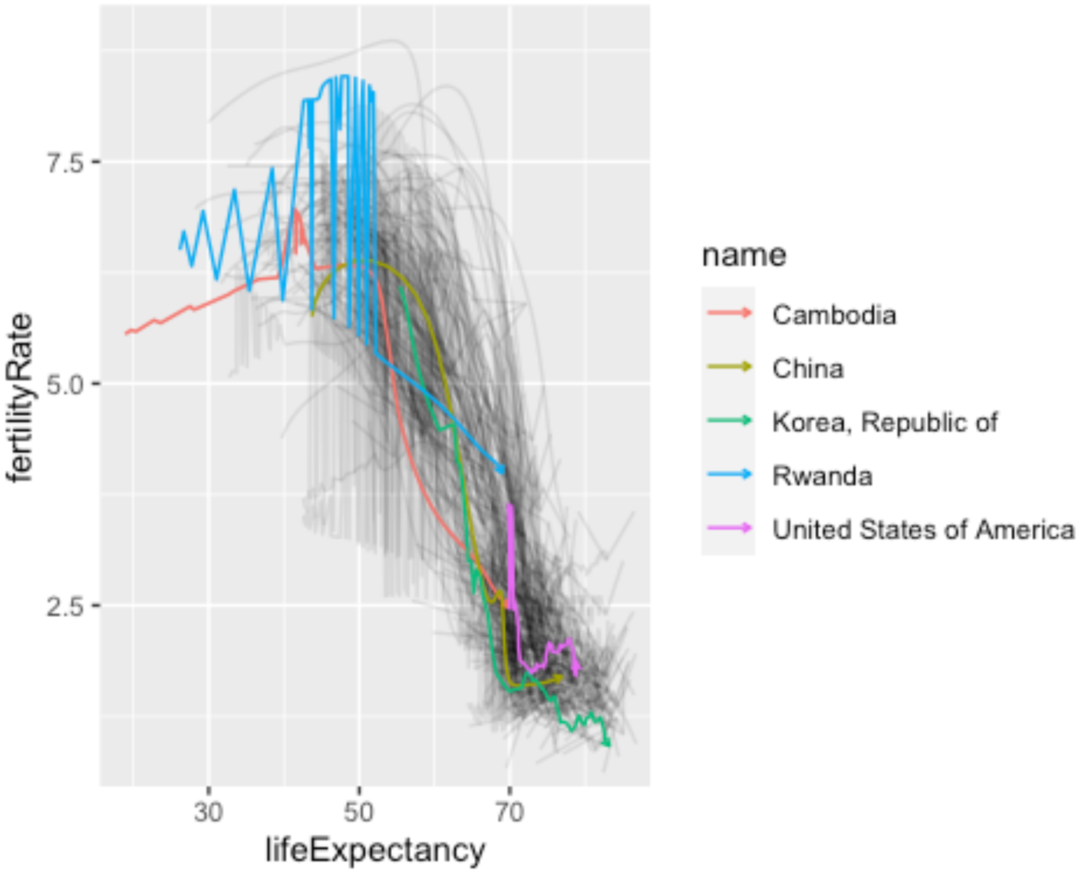


Life expectancy seems to be increasing over the years, probably due to better better health care and hygiene, healthier lifestyles, diet, and improved medical care. China's life expectancy improved greatly during the 70s. United States and Korea too has had a better life expectancy over the years. There are dips in Cambodia and Rwanda's life expectancy due to genocide and tragic killings in the country.

Looking at how life expectancy and fertility are related. Made a fertility rate versus life expectancy plot of all countries with selected countries highlighted. Used arrows to mark which way the time goes on the figure.

```
plot <- ggplot(data=data, aes(x=lifeExpectancy, y=fertilityRate, group=name,
fill="gray")) +
    geom_line(alpha=0.1,arrow = arrow())
plot=plot+geom_line(data=data_subset, aes(x=lifeExpectancy, y=fertilityRate,
group=name, color=name),arrow = arrow(length=unit(0.10,"cm")))
plot
```

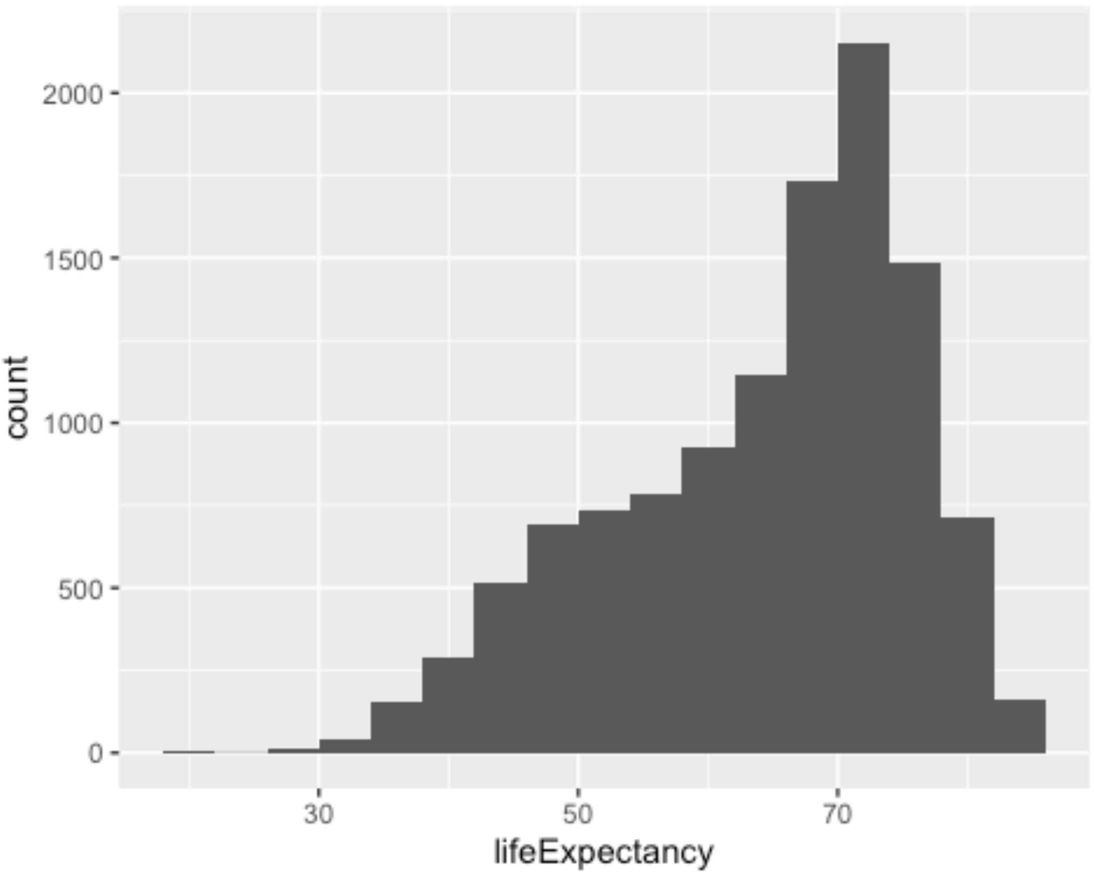
```
## Warning: Removed 13 row(s) containing missing values (geom_path).
```



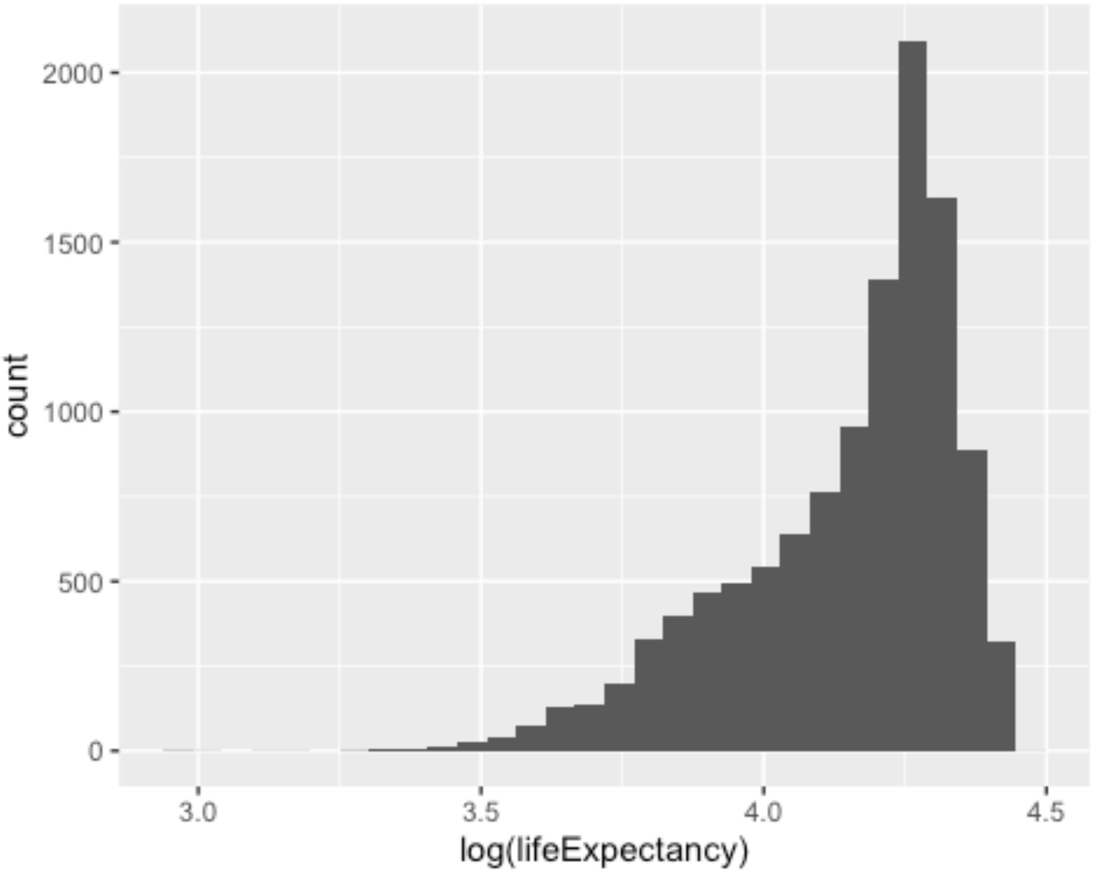
Fertility rate is decreasing while life expectancy is increasing over time. The reason why fertility rate could be decreasing might be because of women empowerment in education and the workforce, lower child mortality and the increased cost of raising children. The highlighted countries are also following the same trend.

Displaying the distribution of life expectancy. It is a little left skewed. We can try log-transformation to see if it distributes the data more normally. Log transformation is making it more left skewed, it would be better to not perform log transformation in this case.

```
library(ggplot2)
ggplot(data, aes(x=lifeExpectancy)) +
    geom_histogram(binwidth=4)
```



```
library(ggplot2)
ggplot(data, aes(x=log(lifeExpectancy))) +
    geom_histogram(bins=30)
```



Created a model to explain life expectancy with just time, where t is time (year). Used year – 2000 instead of just year for time.Since the data has data points far from each other, scaling technique will help make them closer to each other or in simpler words, scaling will make the data points generalized so that the distance between them will be lower. If the difference between the data points is very high, the model could be unstable, which would result in the model producing poor results. Another reason why this makes more sense is the intercept comes as negative without changing the year, and since life expectancy cannot be negative, it makes sense to scale the data.

```
data$mod_year=data$year-2000
head(data)
```

```
##   iso3  name iso2   region                      sub.region
intermediate.region
## 1  ABW Aruba   AW Americas Latin America and the Caribbean
Caribbean
## 2  ABW Aruba   AW Americas Latin America and the Caribbean
Caribbean
## 3  ABW Aruba   AW Americas Latin America and the Caribbean
Caribbean
## 4  ABW Aruba   AW Americas Latin America and the Caribbean
Caribbean
## 5  ABW Aruba   AW Americas Latin America and the Caribbean
```

```
Caribbean
## 6  ABW Aruba   AW Americas Latin America and the Caribbean
Caribbean
##   year totalPopulation fertilityRate lifeExpectancy childMortality
## 1 1960           54211         4.820         65.662             NA
## 2 1961           55438         4.655         66.074             NA
## 3 1962           56225         4.471         66.444             NA
## 4 1963           56695         4.271         66.787             NA
## 5 1964           57032         4.059         67.113             NA
## 6 1965           57360         3.842         67.435             NA
##   youthFemaleLiteracy youthMaleLiteracy adultLiteracy GDP_PC
accessElectricity
## 1                  NA                NA            NA     NA
NA
## 2                  NA                NA            NA     NA
NA
## 3                  NA                NA            NA     NA
NA
## 4                  NA                NA            NA     NA
NA
## 5                  NA                NA            NA     NA
NA
## 6                  NA                NA            NA     NA
NA
##   agriculturalLand agricultureTractors cerealProduction fertilizerHa
co2
## 1               NA                  NA               NA           NA
11092.67
## 2               20                  NA               NA           NA
11576.72
## 3               20                  NA               NA           NA
12713.49
## 4               20                  NA               NA           NA
12178.11
## 5               20                  NA               NA           NA
11840.74
## 6               20                  NA               NA           NA
10623.30
##   greenhouseGases   co2_PC pm2.5_35 battleDeaths mod_year
## 1              NA 204.6204       NA           NA      -40
## 2              NA 208.8228       NA           NA      -39
## 3              NA 226.1181       NA           NA      -38
## 4              NA 214.8004       NA           NA      -37
## 5              NA 207.6158       NA           NA      -36
## 6              NA 185.2040       NA           NA      -35
```

```
model<-lm(lifeExpectancy~mod_year,data=data)
summary(model)
```

```
##
## Call:
## lm(formula = lifeExpectancy ~ mod_year, data = data)
##
## Residuals:
##     Min      1Q  Median      3Q     Max
## -41.382  -7.605   2.549   8.025  18.524
##
## Coefficients:
##              Estimate Std. Error t value Pr(>|t|)
## (Intercept) 67.409244   0.109537  615.40   <2e-16 ***
## mod_year     0.309587   0.005457   56.73   <2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 10.15 on 11556 degrees of freedom
## Multiple R-squared:  0.2179, Adjusted R-squared:  0.2178
## F-statistic:  3219 on 1 and 11556 DF,  p-value: < 2.2e-16
```

b0 here is 67.40, which is the life expectancy when the year is 0, and b1 is 0.30 which is the coefficient of how year parameter affects the life expectancy.

Moving to multiple regression: Estimated the model where I also add the continent (variable region)

```
model1<-lm(lifeExpectancy~mod_year+region,data=data)
summary(model1)
```

```
##
## Call:
## lm(formula = lifeExpectancy ~ mod_year + region, data = data)
##
## Residuals:
##     Min      1Q  Median      3Q     Max
## -42.161  -4.072   0.549   4.032  20.104
##
## Coefficients:
##                  Estimate Std. Error t value Pr(>|t|)
## (Intercept)    55.890766   0.124278  449.72   <2e-16 ***
## mod_year        0.305604   0.003585   85.23   <2e-16 ***
## regionAmericas 15.931152   0.183175   86.97   <2e-16 ***
## regionAsia     12.206582   0.170420   71.63   <2e-16 ***
## regionEurope   20.890772   0.181252  115.26   <2e-16 ***
## regionOceania  13.630385   0.265561   51.33   <2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 6.666 on 11552 degrees of freedom
## Multiple R-squared:  0.6625, Adjusted R-squared:  0.6623
## F-statistic:  4535 on 5 and 11552 DF,  p-value: < 2.2e-16
```

The region dummies are Americas, Asia, Europe and Oceania. The reference category is Africas. The p value for time trend is <2e-16. The time trend is statistically significant as the probability is less than 0.05. This model performs better than the previous one, since the r square value is higher here.

Added two additional variables to the model: log of GDP per capita, and fertility rate. Estimated this model.This model performs better as the adjusted R square is 0.8485, which is higher the the previous two models.

```
model2<-
lm(lifeExpectancy~mod_year+region+fertilityRate+log(GDP_PC),data=data)
summary(model2)
```

```
##
## Call:
## lm(formula = lifeExpectancy ~ mod_year + region + fertilityRate +
##     log(GDP_PC), data = data)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -23.3227  -2.4592   0.2857   2.7112  12.2179
##
## Coefficients:
##                 Estimate Std. Error t value Pr(>|t|)
## (Intercept)    50.028329   0.507479   98.58   <2e-16 ***
## mod_year        0.138053   0.003539   39.01   <2e-16 ***
## regionAmericas  5.939633   0.160004   37.12   <2e-16 ***
## regionAsia      5.750250   0.150353   38.24   <2e-16 ***
## regionEurope    5.292292   0.207486   25.51   <2e-16 ***
## regionOceania   5.665935   0.224681   25.22   <2e-16 ***
## fertilityRate  -2.250470   0.046215  -48.70   <2e-16 ***
## log(GDP_PC)     2.496868   0.046916   53.22   <2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 4.33 on 8930 degrees of freedom
##   (2620 observations deleted due to missingness)
## Multiple R-squared:  0.8486, Adjusted R-squared:  0.8485
## F-statistic:  7150 on 7 and 8930 DF,  p-value: < 2.2e-16
```

All betas are statistically significant. Fertility rate intercept is now negative. The region dummy values have changed a bit. Europe was the leading region before, but now Americas is leading the pack in terms of the value.Additional variables made the ranking of the continents look different as each additional variable brings new beta which alters how the parameters are interacting with the dependent variable.

Based on the most recent model, Americas has the highest life expectancy followed by Asia then Oceania then Europe. We come to this conclusion from the beta values.