Understanding World Population Dynamics

Assignment 1 - PSYC593

Yiwen Wang

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Understanding population dynamics is important for many areas of social science. We will calculate some basic demographic quantities of births and deaths for the world's population from two time periods: 1950 to 1955 and 2005 to 2010. We will analyze the following CSV data files - `Kenya.csv`, `Sweden.csv`, and `World.csv`. Each file contains population data for Kenya, Sweden, and the world, respectively. The table below presents the names and descriptions of the variables in each data set.

Name	Description
`country`	Abbreviated country name
`period`	Period during which data are collected
`age`	Age group
`births`	Number of births in thousands (i.e., number of children born to women of the age group)
`deaths`	Number of deaths in thousands
`py.men`	Person-years for men in thousands
`py.women`	Person-years for women in thousands

Source: United Nations, Department of Economic and Social Affairs, Population Division (2013). *World Population Prospects: The 2012 Revision, DVD Edition.*

```
# Load packages ----
library(stats)
library(rprojroot)
library(here)
```

```
here() starts at /Users/yiwen/Desktop/psyc593_data/01_-_Assignment_1_-_Wang
```

```r
library(readr)
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
```

```r
library(ggplot2)
```

```r
### Path variables ----
# Root directory:
root_path <- here::here()
# Some of the subdirectories
code_path <- file.path(root_path, "src")
docs_path <- here::here("doc")
data_path <- file.path(root_path, "data")
figs_path <- file.path(root_path, "results", "figures")
```

```r
### Read data ----
world_data <- read_csv(file = file.path(data_path, "World.csv"), show_col_types = FALSE)
kenya_data <- read_csv(file = file.path(data_path, "Kenya.csv"), show_col_types = FALSE)
sweden_data <- read_csv(file = file.path(data_path, "Sweden.csv"), show_col_types = FALSE)
```

The data are collected for a period of 5 years where *person-year* is a measure of the time contribution of each person during the period. For example, a person that lives through the entire 5 year period contributes 5 person-years whereas someone who only lives through the first half of the period contributes 2.5 person-years. Before you begin this exercise, it would be a good idea to directly inspect each data set. In R, this can be done with the `View` function, which takes as its argument the name of a `data.frame` to be examined. Alternatively, in RStudio, double-clicking a `data.frame` in the `Environment` tab will enable you to view the data in a spreadsheet-like view.

Question 1

We begin by computing *crude birth rate* (CBR) for a given period. The CBR is defined as:

$$\text{CBR} = \frac{\text{number of births}}{\text{number of person-years lived}}$$

Compute the CBR for each period, separately for Kenya, Sweden, and the world. Start by computing the total person-years, recorded as a new variable within each existing `data.frame` via the `$` operator, by summing the person-years for men and women. Then, store the results as a vector of length 2 (CBRs for two periods) for each region with appropriate labels. You may wish to create your own function for the purpose of efficient programming. Briefly describe patterns you observe in the resulting CBRs.

Answer 1

```r
# Create new variable py = total person years for each data set
world_data$py <- world_data$py.men + world_data$py.women
kenya_data$py <- kenya_data$py.men + kenya_data$py.women
sweden_data$py <- sweden_data$py.men + sweden_data$py.women
```

```r
# Function to compute the Crude Birth Rate (CBR)
compute_cbr <- function(populationData) {
  populationData %>%
    group_by(period) %>%
    summarise(cbr = sum(births) / sum(py)) %>%
    pull()
}
```

```r
# Compute the CBR for each data set

(world_cbr <- compute_cbr(world_data))
```

```
[1] 0.03732863 0.02021593
```

```r
(kenya_cbr <- compute_cbr(kenya_data))
```

```
[1] 0.05209490 0.03851507
```

```r
(sweden_cbr <- compute_cbr(sweden_data))
```

```
[1] 0.01539614 0.01192554
```

In general, the CBRs have decreased comparing 2005-2010 period with 1950-1955 period. The world's CBR during 1950-1955 period is 0.0373286 and during 2005-2010 period is 0.0202159. Kenya's CBR during 1950-1955 period is 0.0520949 and during 2005-2010 period is 0.0385151. Sweden's CBR during 1950-1955 period is 0.0153961 and during 2005-2010 period is 0.0119255.

Question 2

The CBR is easy to understand but contains both men and women of all ages in the denominator. We next calculate the *total fertility rate* (TFR). Unlike the CBR, the TFR adjusts for age compositions in the female population. To do this, we need to first calculate the *age specific fertility rate* (ASFR), which represents the fertility rate for women of the reproductive age range $[15, 50)$. The ASFR for age range $[x, x + \delta)$, where x is the starting age and δ is the width of the age range (measured in years), is defined as:

$$\text{ASFR}_{[x,\ x+\delta)} = \frac{\text{number of births to women of age } [x,\ x+\delta)}{\text{Number of person-years lived by women of age } [x,\ x+\delta)}$$

Note that square brackets, [and], include the limit whereas parentheses, (and), exclude it. For example, $[20, 25)$ represents the age range that is greater than or equal to 20 years old and less than 25 years old. In typical demographic data, the age range δ is set to 5 years. Compute the ASFR for Sweden and Kenya as well as the entire world for each of the two periods. Store the resulting ASFRs separately for each region. What does the pattern of these ASFRs say about reproduction among women in Sweden and Kenya?

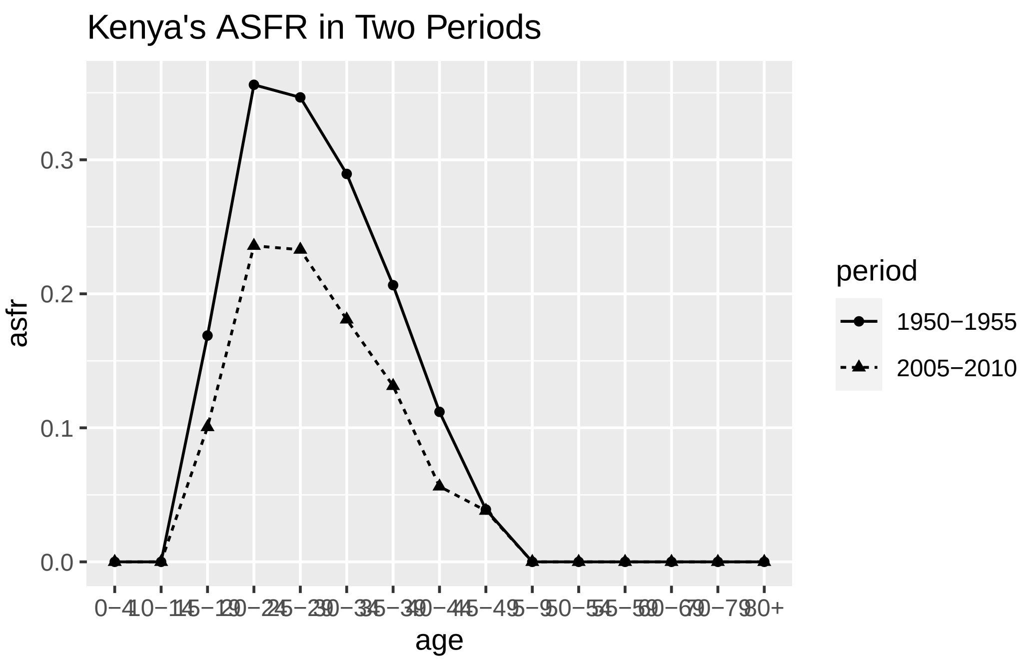
Answer 2

```r
# Function to compute Age specific fertility rate (ASFR)
compute_asfr <- function(pop_data) {
  pop_data %>%
    mutate(asfr = births / py.women)
}
```

```r
# Compute ASFR for each data set
world_data  <- compute_asfr(world_data)
kenya_data  <- compute_asfr(kenya_data)
```

```r
sweden_data <- compute_asfr(sweden_data)
```

```r
# plot kenya's asfr
ggplot(kenya_data, aes(x = age, y = asfr, group = period)) +
  geom_line(aes(linetype = period)) +
  geom_point(aes(shape = period)) +
  ggtitle("Kenya's ASFR in Two Periods")
```




```r
# plot sweden's asfr
ggplot(sweden_data, aes(x = age, y = asfr, group = period)) +
  geom_line(aes(linetype = period)) +
  geom_point(aes(shape = period)) +
  ggtitle("Sweden's ASFR in Two Periods")
```

In general Kenya had smaller ASFRs than Sweden in both periods. From the figures of ASFRs across ages during two periods, we can find that the patterns changed differently between Kenya and Sweden. In Kenya, there was a general decrease in ASFR and the peak was still at 20-24 and 25-29 groups. In Sweden, the ASFR' values didn't drop but the peak was delayed from 20-24 to 30-34.

Question 3

Using the ASFR, we can define the TFR as the average number of children women give birth to if they live through their entire reproductive age.

$$\text{TFR} = \text{ASFR}_{[15,\ 20)} \times 5 + \text{ASFR}_{[20,\ 25)} \times 5 + \cdots + \text{ASFR}_{[45,\ 50)} \times 5$$

We multiply each age-specific fertility rate rate by 5 because the age range is 5 years. Compute the TFR for Sweden and Kenya as well as the entire world for each of the two periods. As in the previous question, continue to assume that women's reproductive age range is $[15, 50)$. Store the resulting two TFRs for each country or the world as a vector of length two. In general, how has the number of women changed in the world from 1950 to 2000? What about the total number of births in the world?

Answer 3

```r
# Function to compute the total fertility rate (TFR)

compute_tfr <- function(population_data) {
  population_data %>%
    group_by(period) %>%
    summarise(tfr = 5 * sum(asfr)) %>%
    pull()
}
```

```r
# Compute the TFR for each data set
(world_tfr <- compute_tfr(world_data))
```

```
[1] 5.007248 2.543623
```

```r
(kenya_tfr <- compute_tfr(kenya_data))
```

```
[1] 7.591410 4.879568
```

```r
(sweden_tfr <- compute_tfr(sweden_data))
```

```
[1] 2.226917 1.902764
```

TFRs decreased in both Kenya and Sweden, as well as in the entire world.

```r
# Compute totals of women and births in the world by period
(totals_world <- world_data %>%
  group_by(period) %>%
  summarise(
    total_women = sum(py.women),
    total_births = sum(births)
  )
)
```

```
# A tibble: 2 x 3
  period    total_women total_births
```

```
  <chr>           <dbl>       <dbl>
1 1950-1955     6555686.     488892.
2 2005-2010    16554781.     674581.
```

```r
# Compare how much these totals have changed
(changes_totals <- totals_world[2, -1] / totals_world[1, -1])
```

```
  total_women total_births
1    2.525256     1.379818
```

In general, both the number of women and the number of births increased from 1950 to 2000, but the number of women increased more than the number of births.

Question 4

Next, we will examine another important demographic process: death. Compute the *crude death rate* (CDR), which is a concept analogous to the CBR, for each period and separately for each region. Store the resulting CDRs for each country and the world as a vector of length two. The CDR is defined as:

$$\text{CDR} = \frac{\text{number of deaths}}{\text{number of person-years lived}}$$

Briefly describe patterns you observe in the resulting CDRs.

Answer 4

```r
# Function to compute the Crude death rate (CDR)
compute_cdr <- function(population_data) {
  population_data %>%
    group_by(period) %>%
    summarise(cbr = sum(deaths) / sum(py)) %>%
    pull()
}
```

```r
# Compute the CDR for each data set
(world_cdr <- compute_cdr(world_data))
```

```
[1] 0.019318929 0.008166083
```

```r
(kenya_cdr <- compute_cdr(kenya_data))
```

```
[1] 0.02396254 0.01038914
```

```r
(sweden_cdr <- compute_cdr(sweden_data))
```

```
[1] 0.009844842 0.009968455
```

In general, the CDRs have decreased comparing 2005-2010 period with 1950-1955 period in Kenya and in the entire wold, but increased a little in Sweden. The world's CDR during 1950-1955 period is 0.0193189 and during 2005-2010 period is 0.0081661. Kenya's CDR during 1950-1955 period is 0.0239625 and during 2005-2010 period is 0.0103891. Sweden's CDR during 1950-1955 period is 0.0098448 and during 2005-2010 period is 0.0099685.

Question 5

One puzzling finding from the previous question is that the CDR for Kenya during the period of 2005-2010 is about the same level as that for Sweden. We would expect people in developed countries like Sweden to have a lower death rate than those in developing countries like Kenya. While it is simple and easy to understand, the CDR does not take into account the age composition of a population. We therefore compute the *age specific death rate* (ASDR). The ASDR for age range $[x, x + \delta)$ is defined as:

$$\text{ASDR}_{[x,\ x+\delta)} = \frac{\text{number of deaths for people of age } [x,\ x+\delta)}{\text{number of person-years of people of age } [x,\ x+\delta)}$$

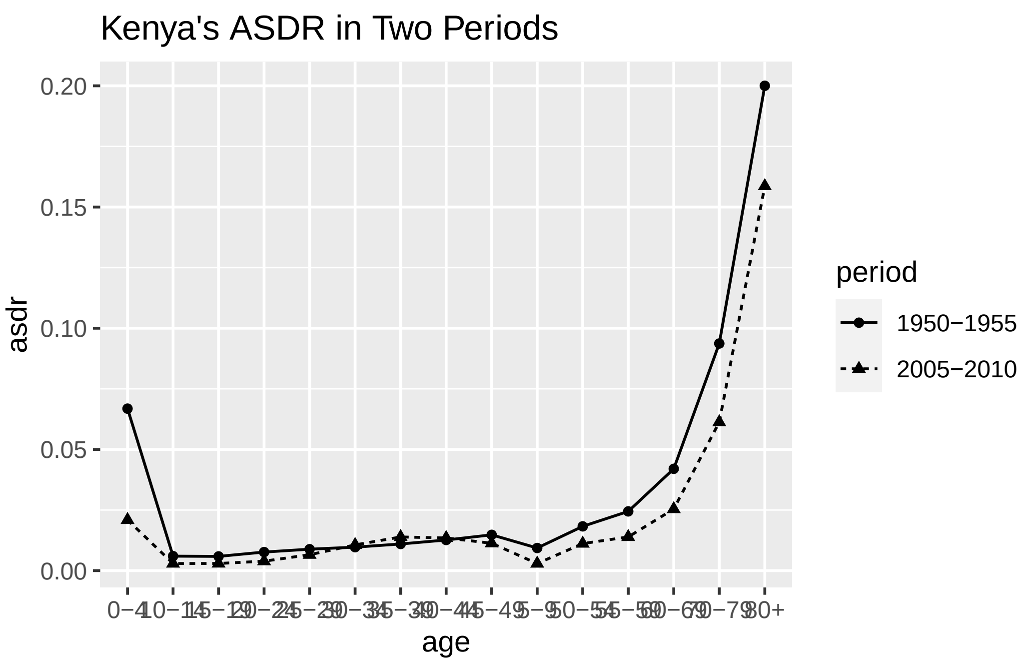
Calculate the ASDR for each age group, separately for Kenya and Sweden, during the period of 2005-2010. Briefly describe the pattern you observe.

Answer 5

```r
# Function to compute Age specific death rate (ASDR)
compute_asdr <- function(pop_data) {
  pop_data %>%
    mutate(asdr = deaths / py)
}
```

```r
# Compute ASDR for each data set
world_data <- compute_asdr(world_data)
kenya_data <- compute_asdr(kenya_data)
sweden_data <- compute_asdr(sweden_data)
```

```r
# plot kenya's ASDR
ggplot(kenya_data, aes(x = age, y = asdr, group = period)) +
  geom_line(aes(linetype = period)) +
  geom_point(aes(shape = period)) +
  ggtitle("Kenya's ASDR in Two Periods")
```




```r
# plot sweden's ASDR
ggplot(sweden_data, aes(x = age, y = asdr, group = period)) +
  geom_line(aes(linetype = period)) +
  geom_point(aes(shape = period)) +
  ggtitle("Sweden's ASDR in Two Periods")
```

Sweden had smaller ASDRs in both young children and older adults than Kenya.

Question 6

One way to understand the difference in the CDR between Kenya and Sweden is to compute the counterfactual CDR for Kenya using Sweden's population distribution (or vice versa). This can be done by applying the following alternative formula for the CDR.

$$\text{CDR} \;=\; \text{ASDR}_{[0,5)} \times P_{[0,5)} + \text{ASDR}_{[5,10)} \times P_{[5,10)} + \cdots$$

where $P_{[x,x+\delta)}$ is the proportion of the population in the age range $[x, x+\delta)$. We compute this as the ratio of person-years in that age range relative to the total person-years across all age ranges. To conduct this counterfactual analysis, we use $\text{ASDR}_{[x,x+\delta)}$ from Kenya and $P_{[x,x+\delta)}$ from Sweden during the period of 2005–2010. That is, first calculate the age-specific population proportions for Sweden and then use them to compute the counterfactual CDR for Kenya. How does this counterfactual CDR compare with the original CDR of Kenya? Briefly interpret the result.

Answer 6

```r
# Function to compute population proportion by period
compute_pop_prop <- function(pop_data) {
  pop_data %>%
    group_by(period) %>%
    mutate(popP = py / sum(py)) %>%
    ungroup()
}
```

```r
# Compute population proportion for each data set
world_data <- compute_pop_prop(world_data)
kenya_data <- compute_pop_prop(kenya_data)
sweden_data <- compute_pop_prop(sweden_data)
```

```r
# Compute Kenyas CDR Kenya had Sweden's population distribution
mutate(kenya_data,
  temp_cdr = asdr * sweden_data$popP
) %>%
  group_by(period) %>%
  summarise(cdrresweden = sum(temp_cdr))
```

```
# A tibble: 2 x 2
  period    cdrresweden
  <chr>           <dbl>
1 1950-1955      0.0257
2 2005-2010      0.0232
```