project1

September 27, 2024

[106]:
```python
# Initialize Otter
import otter
grader = otter.Notebook("project1.ipynb")
```

1 Project 1: World Population and Poverty

In this project, you'll explore data from Gapminder.org, a website dedicated to providing a fact-based view of the world and how it has changed. That site includes several data visualizations and presentations, but also publishes the raw data that we will use in this project to recreate and extend some of their most famous visualizations.

The Gapminder website collects data from many sources and compiles them into tables that describe many countries around the world. All of the data they aggregate are published in the Systema Globalis. Their goal is "to compile all public statistics; Social, Economic and Environmental; into a comparable total dataset." All data sets in this project are copied directly from the Systema Globalis without any changes.

This project is dedicated to Hans Rosling (1948-2017), who championed the use of data to understand and prioritize global development challenges.

1.0.1 Logistics

Deadline. This project is due at **5:00pm PT on Friday 10/4**. Projects will be accepted up to 1 day (24 hours) late. Projects submitted fewer than 24 hours after the deadline will receive 80% credit. It's **much** better to be early than late, so start working now.

Checkpoint. For full credit on the checkpoint, you must complete the questions up to the checkpoint, **pass all *public* autograder tests** for those sections, and submit to the Gradescope Project 1 Checkpoint assignment by **5:00pm PT on Friday, 9/27**. **The checkpoint is worth 5% of your entire project grade**. After you've submitted the checkpoint, you may still change your project answers before the final project deadline - only your final submission, to the "Project 1" assignment, will be graded for correctness. You will have some lab time to work on these questions, but we recommend that you start the project before lab and leave time to finish the checkpoint afterward.

Partners. You may work with one other partner; your partner must be from your assigned lab section. **Only one partner should submit the project notebook to Gradescope. If both partners submit, you will be docked 10% of your project grade. On Gradescope, the person who submits should also designate their partner so that both of you receive**

credit. Once you submit, click into your submission, and there will be an option to Add Group Member in the top right corner. You may also reference this walkthrough video on how to add partners on Gradescope.

Rules. Don't share your code with anybody but your partner. You are welcome to discuss questions with other students, but don't share the answers. The experience of solving the problems in this project will prepare you for exams (and life). If someone asks you for the answer, resist! Instead, you can demonstrate how you would solve a similar problem.

Support. You are not alone! Come to office hours, post on Ed, and talk to your classmates. If you want to ask about the details of your solution to a problem, make a private Ed post and the staff will respond. If you're ever feeling overwhelmed or don't know how to make progress, email your TA or tutor for help. You can find contact information for the staff on the course website.

Tests. The tests that are given are **not comprehensive** and passing the tests for a question **does not** mean that you answered the question correctly. Tests usually only check that your table has the correct column labels. However, more tests will be applied to verify the correctness of your submission in order to assign your final score, so be careful and check your work! You might want to create your own checks along the way to see if your answers make sense. Additionally, before you submit, make sure that none of your cells take a very long time to run (several minutes).

Free Response Questions: Make sure that you put the answers to the written questions in the indicated cell we provide. **Every free response question should include an explanation** that adequately answers the question.

Tabular Thinking Guide: Feel free to reference Tabular Thinking Guide for extra guidance.

Advice. Develop your answers incrementally. To perform a complicated table manipulation, break it up into steps, perform each step on a different line, give a new name to each result, and check that each intermediate result is what you expect. You can add any additional names or functions you want to the provided cells. Make sure that you are using distinct and meaningful variable names throughout the notebook. Along that line, **DO NOT** reuse the variable names that we use when we grade your answers. For example, in Question 1 of the Global Poverty section we ask you to assign an answer to `latest`. Do not reassign the variable name `latest` to anything else in your notebook, otherwise there is the chance that our tests grade against what `latest` was reassigned to.

You are **never** restricted to using only one line of code to solve a question in this project or any others. Feel free to use intermediate variables and multiple lines as much as you would like!

The point breakdown for this assignment is given in the table below: | Category | Points | | — | — | | Autograder (Coding questions) | 60 | | Written | 35 | | Checkpoint | 5 | | **Total** | 100 |

To get started, load `datascience`, `numpy`, `plots`, and `otter`.

[107]:
```
# Run this cell to set up the notebook, but please don't change it.

# These lines import the NumPy and Datascience modules.
from datascience import *
```

```
import numpy as np

# These lines do some fancy plotting magic.
%matplotlib inline
import matplotlib.pyplot as plots
plots.style.use('fivethirtyeight')

from ipywidgets import interact, interactive, fixed, interact_manual
import ipywidgets as widgets
```

1.1 0. Hazards with .show

As a heads up, please do not run the function `tbl.show()` in this assignment without an argument. For instance if you want to view a table, please type `tbl.show(10)` instead of `tbl.show()`. This may break your notebook and we cannot guarantee what we will have the capacity to aid you in this. Please answer the question below, and set the value to `True` to confirm you have read this and agree.

[108]:
```
i_wont_use_show_without_an_argument = True
```

[109]:
```
grader.check("q0")
```

[109]:
```
q0 results: All test cases passed!
```

1.2 1. Global Population Growth

The global population of humans reached 1 billion around 1800, 3 billion around 1960, 7 billion around 2011, and 8 billion around 2022. The potential impact of population growth has concerned scientists, economists, and politicians alike.

The United Nations Population Division estimates that the world population will likely continue to grow throughout the 21st century, but at a slower rate, perhaps reaching and stabilizing at 10 billion by 2100. However, the UN does not rule out scenarios of slower or more extreme growth. These projections help us understand long-term population processes, even if they leave out possible global catastrophic events like war or climate crises.

In this part of the project, we will examine some of the factors that influence population growth and how they have been changing over the years and around the world. There are two main sub-parts of this analysis.

- First, we will examine the data for one country, Poland. We will see how factors such as life expectancy, fertility rate, and child mortality have changed over time in Poland, and how they are related to the rate of population growth.
- Next, we will examine whether the changes we have observed for Poland are particular to that country or whether they reflect general patterns observable in other countries too. We will study aspects of world population growth and see how they have been changing.

The first table we will consider contains the total population of each country over time. Run the cell below.

[110]:
```
population = Table.read_table('population.csv').where("time", are.below(2025))
population.show(3)
```

```
<IPython.core.display.HTML object>
```

Note: The population data can also be found here.

1.2.1 Poland

The Central European nation of Poland has undergone many changes over the centuries. In modern times it was (re)created as a democratic republic in 1919 after World War I. It was invaded and divided in World War II between Germany and the Soviet Union. War and the Holocaust had a devastating impact on its people. Poland was constituted in its current borders at the end of World War II (1945) under a communist government. In 1989, with the fall of the Soviet Union, Poland re-established itself as a democratic republic.

In this section of the project, we will examine aspects of the population of Poland since 1900. Poland's borders have changed, so we will look at the population within its current (2024) borders.

In the `population` table, the `geo` column contains three-letter codes established by the International Organization for Standardization (ISO) in the Alpha-3 standard. **Use the Alpha-3 link to find the 3-letter code for Poland.**

Question 1. Create a table called `p_pop` that has two columns labeled `time` and `population_total`. The first column should contain the years from 1900 through 2024 (including both 1900 and 2024) and the second column should contain the population of Poland in each of those years.

[111]:
```
p_pop = population.where("geo", are.equal_to("pol")).where("time", are.
↪above_or_equal_to(1900)).select("time", "population_total")
p_pop
```

[111]:
```
time | population_total
1900 | 24308265
1901 | 24485193
1902 | 24660489
1903 | 24834119
1904 | 25008969
1905 | 25185047
1906 | 25362361
1907 | 25540920
1908 | 25720733
1909 | 25808244
… (115 rows omitted)
```

[112]:
```
grader.check("q1_1")
```

[112]:
```
q1_1 results: All test cases passed!
```

Run the following cell to create a table called `p_five` that has the population of Poland every five years.

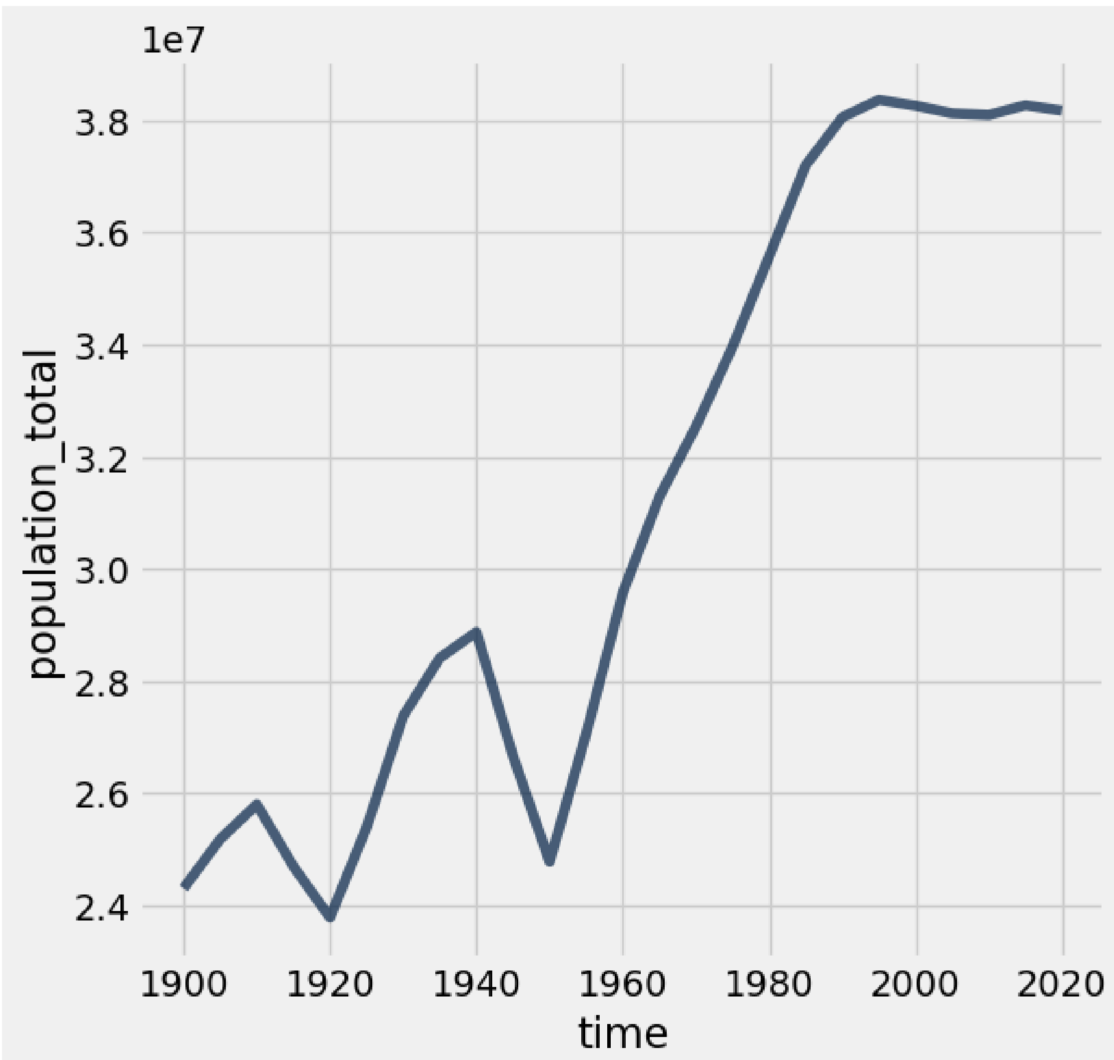
[113]:
```
p_pop.set_format('population_total', NumberFormatter)

fives = np.arange(1900, 2021, 5) # 1900, 1905, 1910, ..., 2020
p_five = p_pop.sort('time').where('time', are.contained_in(fives))
p_five.show(3)
```

<IPython.core.display.HTML object>

Run the following cell to visualize the population over time. Following the devastating effects of World War I and World War II, Poland's population increased steadily from 1950 to 2000 and then leveled off. In the following questions we'll investigate this period of population growth.

[114]:
```
p_five.plot(0, 1)
```



Question 2. Assign `initial` to an array that contains the population for every five year interval from **1900 to 2015** (inclusive). Then, assign `changed` to an array that contains the population for every five year interval from **1905 to 2020** (inclusive). The first array should include both 1900 and 2015, and the second array should include both 1905 and 2020. You should use the `p_five` table to create both arrays, by first filtering the table to only contain the relevant years.

The annual growth rate for a time period is equal to:

$$\left(\left(\frac{\text{Population at end of period}}{\text{Population at start of period}}\right)^{\frac{1}{\text{number of years}}}\right) - 1$$

We have provided the code below that uses `initial` and `changed` in order to add a column to `p_five` called `annual_growth`. **Don't worry about the calculation of the growth rates**; run the test below to test your solution.

If you are interested in how we came up with the formula for growth rates, consult the growth rates section of the textbook.

[115]:
```
initial = p_five.where("time", are.below_or_equal_to(2015)).
 ↪column("population_total")
changed = p_five.where("time", are.between_or_equal_to(1905, 2020)).
 ↪column("population_total")

p_1900_through_2015 = p_five.where('time', are.below_or_equal_to(2015))
p_five_growth = p_1900_through_2015.with_column('annual_growth', (changed/
 ↪initial)**0.2-1)
p_five_growth.set_format('annual_growth', PercentFormatter)
```

[115]:
```
time | population_total | annual_growth
1900 | 24,308,265       | 0.71%
1905 | 25,185,047       | 0.49%
1910 | 25,803,855       | -0.87%
1915 | 24,696,678       | -0.75%
1920 | 23,785,820       | 1.32%
1925 | 25,395,008       | 1.52%
1930 | 27,378,955       | 0.75%
1935 | 28,414,953       | 0.32%
1940 | 28,876,472       | -1.58%
1945 | 26,666,588       | -1.46%
… (14 rows omitted)
```

[116]:
```
grader.check("q1_2")
```

[116]:
```
q1_2 results: All test cases passed!
```

The annual growth rate in Poland has been declining since 1950, as shown in the table below.

```
[117]: # Run this cell to view annual growth rates in Poland since 1950.
p_five_growth.where('time', are.above_or_equal_to(1950)).show()
```

```
<IPython.core.display.HTML object>
```

Next, we'll try to understand what has changed in Poland that might explain the slowing population growth rate. Run the next cell to load three additional tables of measurements about countries over time.

```
[118]: life_expectancy = Table.read_table('life_expectancy.csv').where('time', are.
    ↪below(2025))
child_mortality = Table.read_table('child_mortality.csv').relabel(2,␣
    ↪'child_mortality_under_5_per_1000_born').where('time', are.below(2025))
fertility = Table.read_table('fertility.csv').where('time', are.below(2025))
```

The `life_expectancy` table contains a statistic that is often used to measure how long people live, called *life expectancy at birth*. This number, for a country in a given year, does not measure how long babies born in that year are expected to live. Instead, it measures how long someone would live, on average, if the *mortality conditions* in that year persisted throughout their lifetime. These "mortality conditions" describe what fraction of people for each age survived the year. So, it is a way of measuring the proportion of people that are staying alive, aggregated over different age groups in the population.

Run the following cells below to see `life_expectancy`, `child_mortality`, and `fertility`. Refer back to these tables as they will be helpful for answering further questions!

```
[119]: life_expectancy.show(3)
```

```
<IPython.core.display.HTML object>
```

```
[120]: child_mortality.show(3)
```

```
<IPython.core.display.HTML object>
```

```
[121]: fertility.show(3)
```

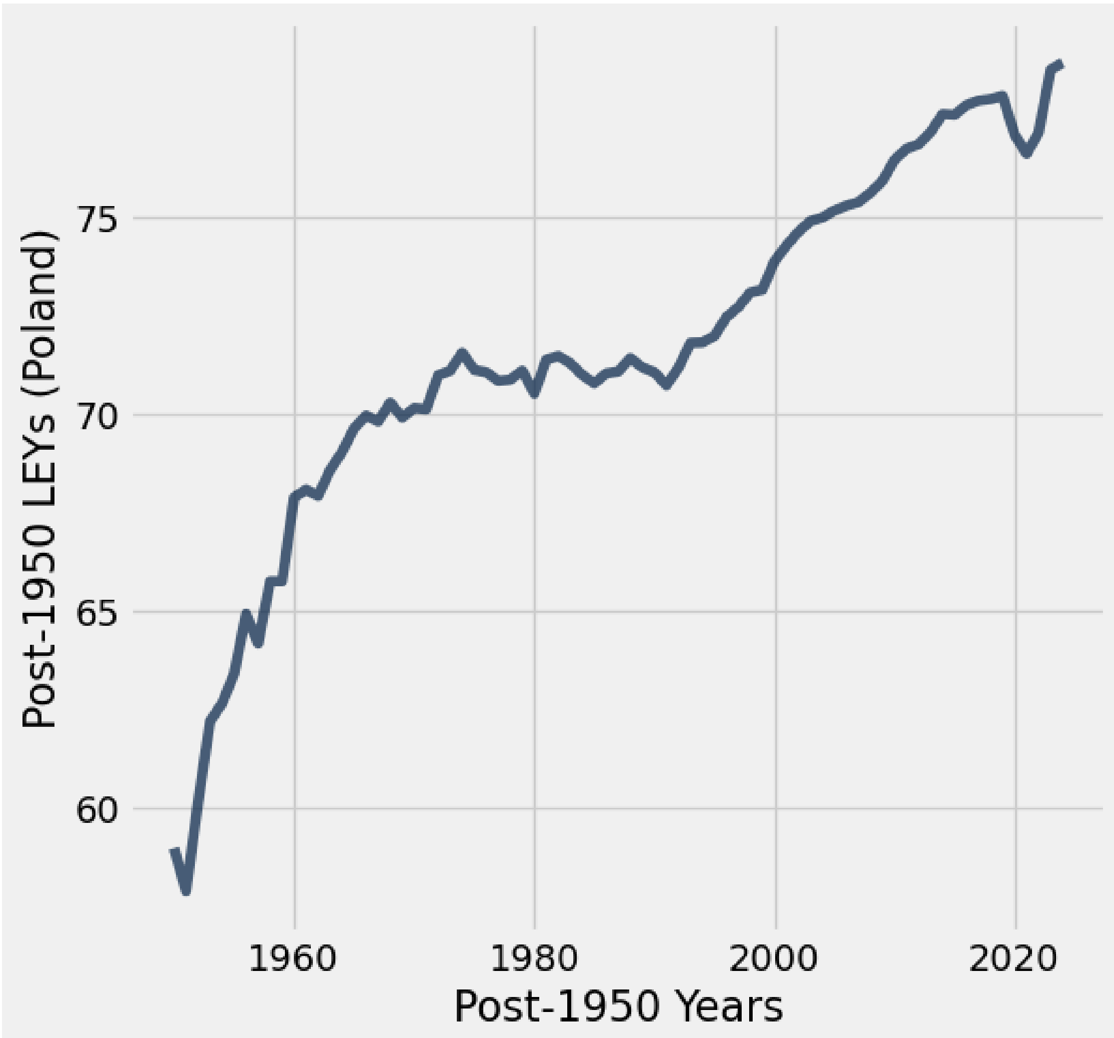
```
<IPython.core.display.HTML object>
```

Question 3. Is population growing more slowly perhaps because people aren't living as long? Use the `life_expectancy` table to draw a line graph with the years 1950 and later on the horizontal axis that shows how the *life expectancy at birth* has changed in Poland.

Hint: Make sure you filter the table properly; otherwise, the graph may look funky!

```
[122]: # Fill in code here
post_1950_data = life_expectancy.where("time", are.above_or_equal_to(1950)).
    ↪where("geo", are.equal_to("pol"))
post_1950_time = post_1950_data.column("time")
post_1950_leys = post_1950_data.column("life_expectancy_years")
```

```
post_1950_table = post_1950_data.with_columns("Post-1950 Years",␣
↪post_1950_time, "Post-1950 LEYs (Poland)", post_1950_leys)
post_1950_table.plot("Post-1950 Years", "Post-1950 LEYs (Poland)")
```



Question 4. Assuming everything else stays the same, do the trends in life expectancy in the graph above directly explain why the population growth rate decreased since 1950 in Poland? Why or why not?

The trends in life expectancy in the graph above do not directly explain the population growth rate decrease since 1950 in Poland. Life expectancy years at birth measures how long someone would live. Thus, the trends in life expectancy in the graph only expain changes in mortality rates, not the population growth rate. To show a decrease in the population growth rate, we would need to compare it with trends in birth rates.

The `fertility` table contains a statistic that is often used to measure how many babies are being born, the *total fertility rate*. This number describes the number of children a woman would have in her lifetime, on average, if the current rates of birth by age of the mother persisted throughout her child bearing years, assuming she survived through age 49.

Question 5. Complete the function `fertility_over_time`. It takes two input arguments, the Alpha-3 code of a country (denoted as `country_code`) and a year to `start` from (denoted as start). It returns a two-column table with the column labels `Year` and `Children per woman`. These columns can be used to generate a line chart of the country's fertility rate each year, starting from the year given by `start`. The plot should include the start year and all later years that appear in the fertility table.

Then, determine the Alpha-3 code for **Poland**. The code at the very bottom for `poland_code` and the year `1950` are inputted to your `fertility_over_time` function. The function returns a table which we use in order to plot how Poland's fertility rate has changed since `1950`. Note that the function `fertility_over_time` should not return the plot itself – it returns a two column table. The expression that draws the line plot is provided for you; please don't change it.

Hint: Read about `tbl.relabeled` in the Python Reference to rename columns.

[123]:
```python
def fertility_over_time(country_code, start):
    """Create a two-column table that describes a country's total fertility␣
 ↪rate each year."""
    # It's a good idea (but not required) to use multiple lines in your␣
 ↪solution.
    fertility_specify = fertility.where("geo", are.equal_to(country_code)).
 ↪where("time", are.above_or_equal_to(start)).select("time",␣
 ↪"children_per_woman_total_fertility")
    country_fertility = fertility_specify.relabeled("time", "Year").
 ↪relabeled("children_per_woman_total_fertility", "Children per woman")
    return country_fertility


poland_code = "pol"
fertility_over_time(poland_code, 1950)
```

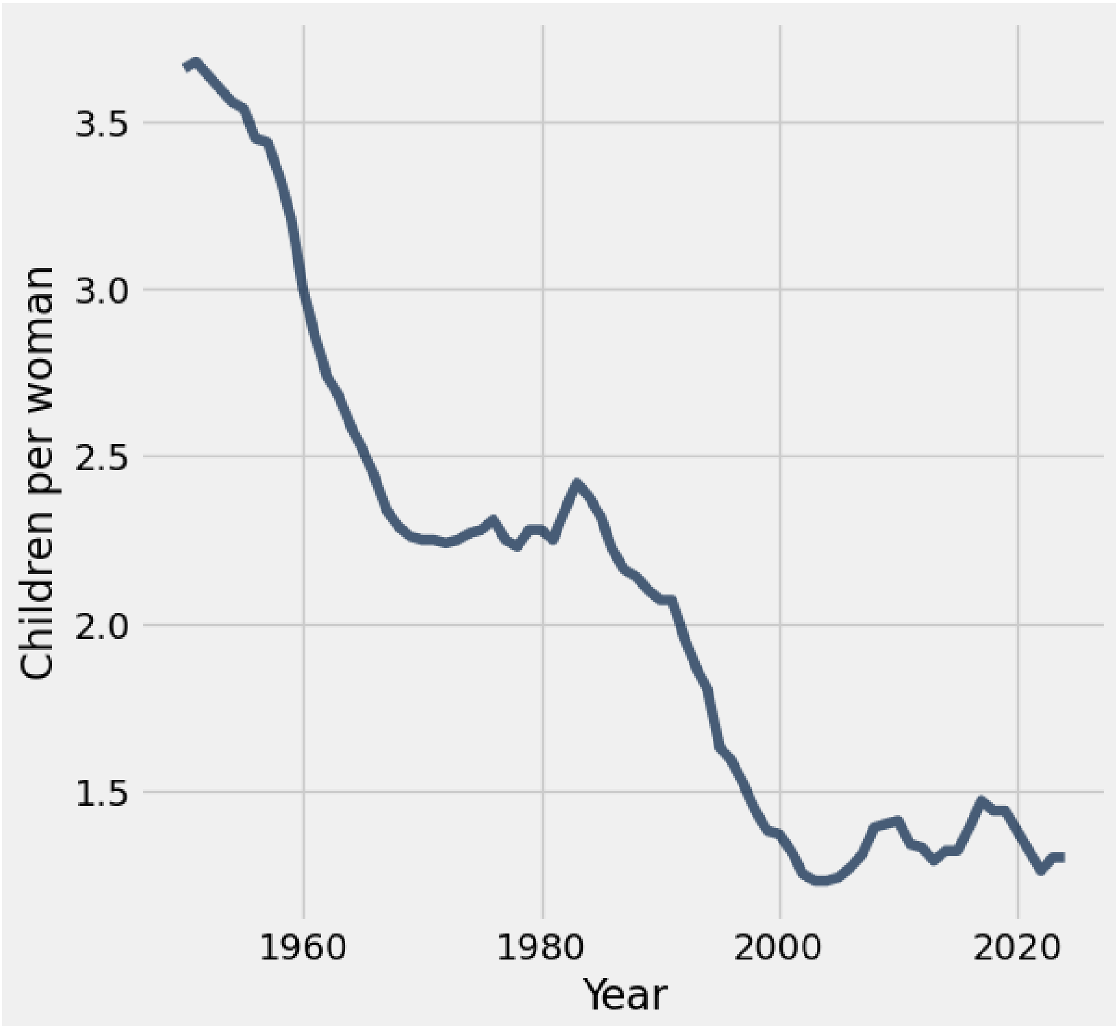
[123]:
```
Year | Children per woman
1950 | 3.66
1951 | 3.68
1952 | 3.64
1953 | 3.6
1954 | 3.56
1955 | 3.54
1956 | 3.45
1957 | 3.44
1958 | 3.34
1959 | 3.21
… (65 rows omitted)
```

[124]:
```
grader.check("q1_5")
```

[124]:
```
q1_5 results: All test cases passed!
```

Plotting the fertility rate in Poland since 1950, we see a downward trend.

[125]:
```
fertility_over_time(poland_code, 1950).plot(0, 1)
```



Question 6. Assuming everything else is constant, do the trends in fertility in the graph above help directly explain why the population growth rate decreased from 1950 to 2020 in Poland? Why or why not?

The trends in fertility in the graph above directly explains why the population growth rate decreased from 1950 to 2020 in Poland. The number of children per woman measures how many babies a woman has in a certain year, which explains changes in the population growth rate. In the line *graph, we see a downward trend in the number of children per woman after 1950. This means that ever since 1950, Polish women gradually had less babies as the years went by, which explains Poland's slow and shrinking population growth rate.*

It has been observed that lower fertility rates are often associated with lower child mortality rates. We can see if this association is evident in Poland by plotting the relationship between total fertility rate and child mortality rate per 1000 children.

Question 7. Create a table `poland_since_1950` that contains one row per year starting with 1950 and:

- A column `Year` containing the year
- A column `Children per woman` describing total fertility in Poland that year
- A column `Child deaths per 1000 born` describing child mortality in Poland that year

[126]:
```
pol_fertility = fertility_over_time(poland_code, 1950)  # Try starting with the␣
↪table you built already!
# It's a good idea (but not required) to use multiple lines in your solution.
pol_child_mortality = child_mortality.where("geo", are.equal_to("pol")).
↪where("time", are.above_or_equal_to(1950)).
↪column("child_mortality_under_5_per_1000_born")
pol_fertility_and_child_mortality = pol_fertility.with_columns("Child deaths␣
↪per 1000 born", pol_child_mortality)
poland_since_1950 = pol_fertility_and_child_mortality
poland_since_1950
```

[126]:
```
Year | Children per woman | Child deaths per 1000 born
1950 | 3.66               | 164.08
1951 | 3.68               | 177.18
1952 | 3.64               | 140.16
1953 | 3.6                | 127.65
1954 | 3.56               | 118.9
1955 | 3.54               | 110.38
1956 | 3.45               | 94.19
1957 | 3.44               | 86.72
1958 | 3.34               | 81.28
1959 | 3.21               | 72.1
… (65 rows omitted)
```

[127]:
```
grader.check("q1_7")
```

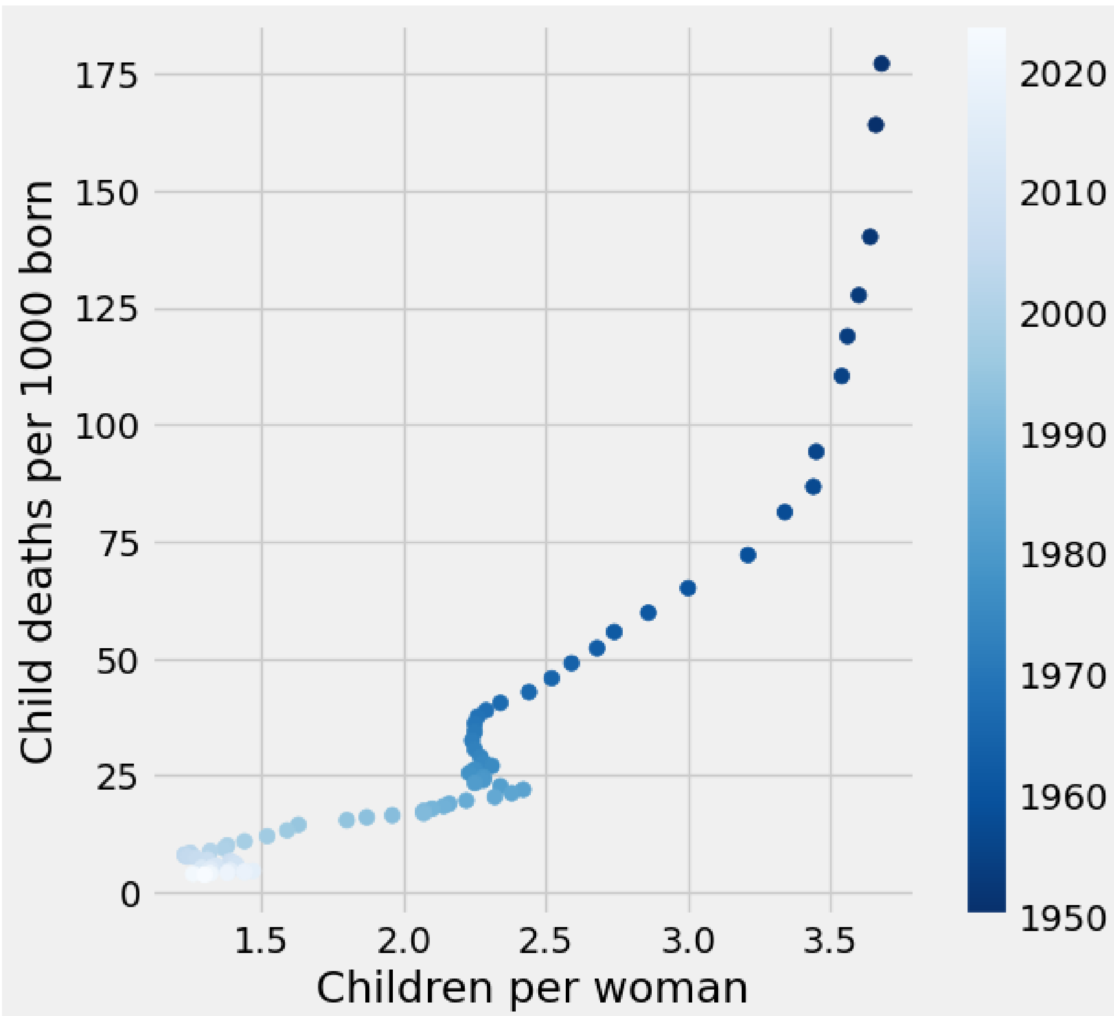
[127]:
```
q1_7 results: All test cases passed!
```

Run the following cell to generate a scatter plot from the `poland_since_1950` table you created.

The plot uses **color** to encode data about the `Year` column. The colors, ranging from dark blue to white, represent the passing of time between 1950 and 2024. For example, a point on the scatter plot representing data from the 1950s would appear as **dark blue** and a point from the 2010s would appear as **light blue**.

[128]:
```
x_births = poland_since_1950.column("Children per woman")
y_deaths = poland_since_1950.column("Child deaths per 1000 born")
time_colors = poland_since_1950.column("Year")

plots.figure(figsize=(6,6))
plots.scatter(x_births, y_deaths, c=time_colors, cmap="Blues_r")
plots.colorbar()
plots.xlabel("Children per woman")
plots.ylabel("Child deaths per 1000 born");
```



Question 8. In one or two sentences, describe the association (if any) that is illustrated by this scatter plot. Does the diagram show any causal relation between between fertility and child mortality?

There is a positive association between higher fertility rates and higher child mortality rates. The scatter plot does not show any causal relation between fertility and child mortality; it only observes the relationship between those two variables.

Optional food for thought: What other context or information you would need in order to better understand the factors affecting life expectancy, child mortality, and fertility?

1.2.2 Checkpoint (due Friday 9/27 by 5:00 PM PT)

WOOOHOO!!! Harvey wants to congratulate you on reaching the checkpoint!

Run the following cells and submit to the Gradescope assignment corresponding to the checkpoint: Project 1 Checkpoint

Remember to add your project partner to your submission on Gradescope! Only one partner should submit to Gradescope.

To double check your work, the cell below will rerun all of the autograder tests for Section 1.

[129]:
```
checkpoint_tests = ["q1_1", "q1_2", "q1_5", "q1_7"]
for test in checkpoint_tests:
    display(grader.check(test))
```

```
q1_1 results: All test cases passed!

q1_2 results: All test cases passed!

q1_5 results: All test cases passed!

q1_7 results: All test cases passed!
```

1.3 Submission

Make sure you have run all cells in your notebook in order before running the cell below, so that all images/graphs appear in the output. The cell below will generate a zip file for you to submit. You only need to submit the zip file for the checkpoint. **Please save before exporting!**

[130]:
```
# Save your notebook first, then run this cell to export your submission.
grader.export(pdf=False)
```

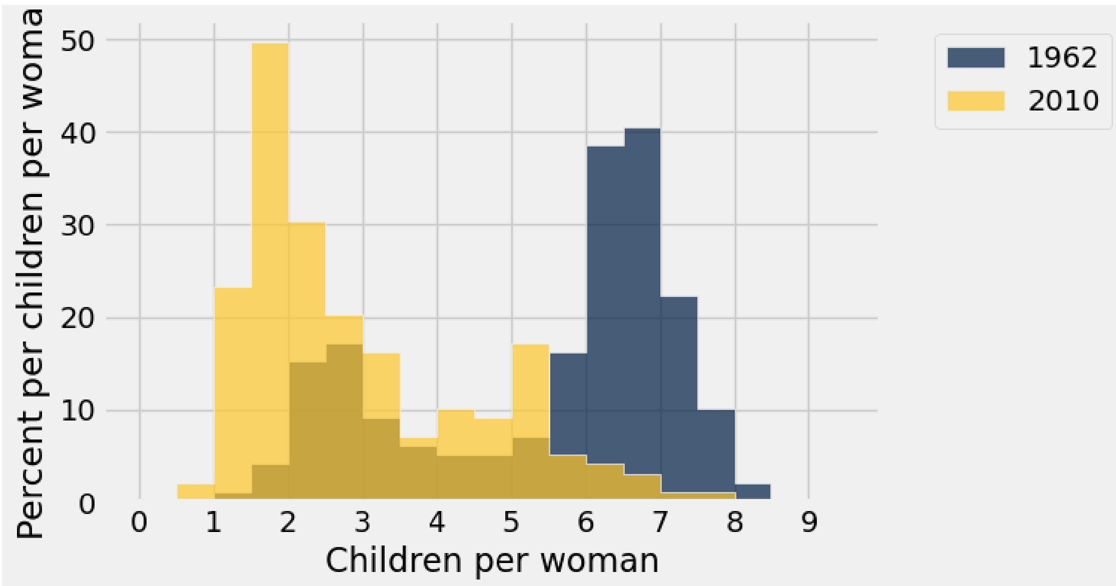
```
<IPython.core.display.HTML object>
```

1.3.1 The World

The changes observed in Poland can also be observed in many other countries: except during periods of extended war, famine, and social chaos, health services generally improve, life expectancy increases, and child mortality decreases. At the same time, the fertility rate often plummets, and where it does, the population growth rate decreases despite increasing longevity.

Run the cell below to generate two overlaid histograms, one for 1962 and one for 2010, that show the distributions of total fertility rates for these two years among all 201 countries in the `fertility` table.

[131]:
```
Table().with_columns(
    '1962', fertility.where('time', 1962).column(2),
    '2010', fertility.where('time', 2010).column(2)
).hist(bins=np.arange(0, 10, 0.5), unit='child per woman')
_ = plots.xlabel('Children per woman')
_ = plots.ylabel('Percent per children per woman')
_ = plots.xticks(np.arange(10))
```



Question 9. Assign `fertility_statements` to an **array** of the numbers of each statement below that can be correctly inferred from these histograms.

1. About the same number of countries had a fertility rate between 3.5 and 4.5 in both 1962 and 2010.
2. In 1962, less than 20% of countries had a fertility rate below 3.
3. At least half of countries had a fertility rate between 5 and 8 in 1962.
4. In 2010, about 40% of countries had a fertility rate between 1.5 and 2.
5. At least half of countries had a fertility rate below 3 in 2010.
6. More countries had a fertility rate above 3 in 1962 than in 2010.

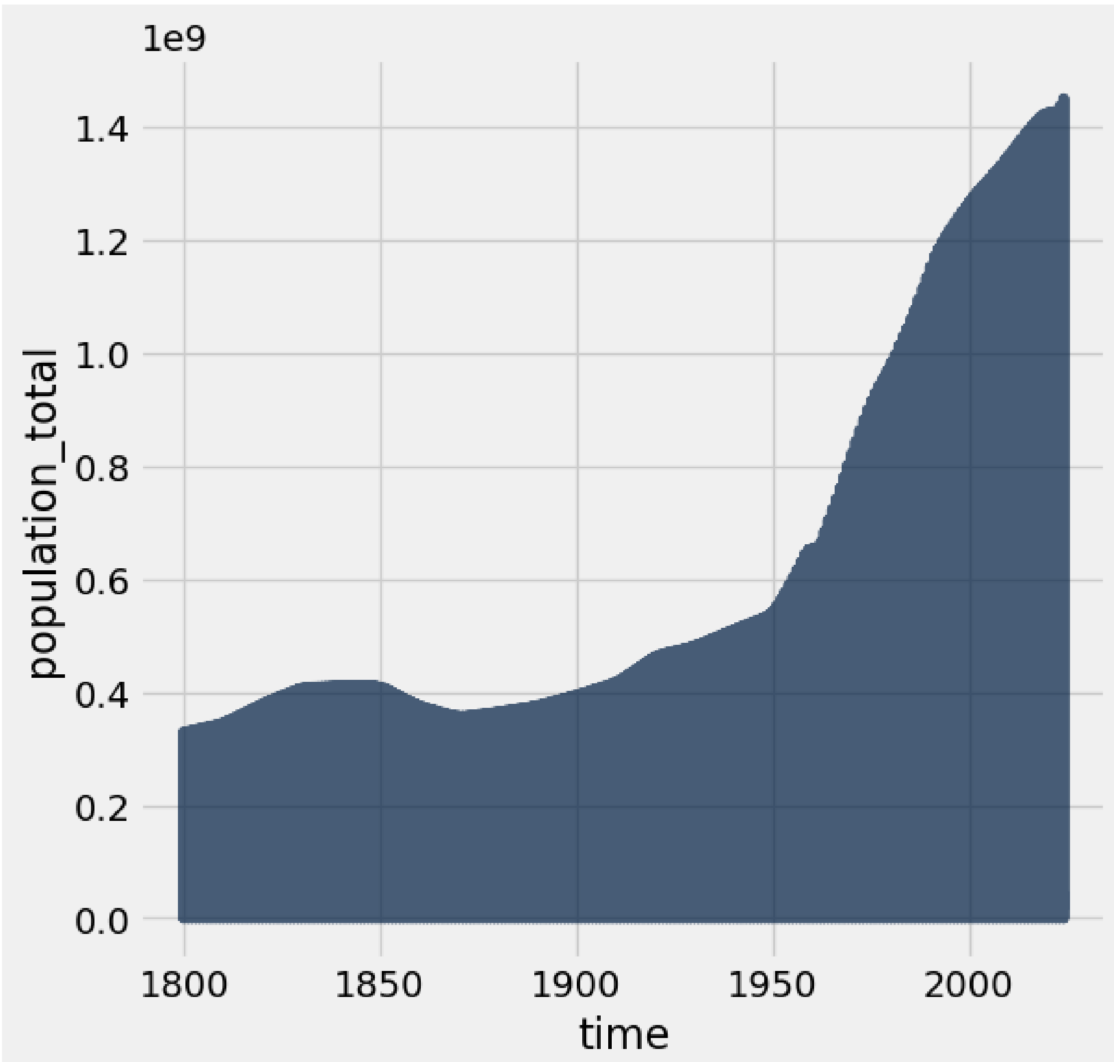
[132]:
```
fertility_statements = make_array(2, 3, 4, 5, 6)
```

[133]:
```
grader.check("q1_9")
```

[133]: q1_9 results: All test cases passed!

Question 10. Draw a line plot of the **world population** from 1800 through 2024 (inclusive of both endpoints). The world population is the sum of all of the countries' populations. You should use the `population` table defined earlier in the project.

[134]:
```
#Fill in code here
population_specified = population.where("time", are.between_or_equal_to(1800,
    2024))
population_specified.plot("time", "population_total")
```



Question 11. Create a function `stats_for_year` that takes a `year` and returns a table of statistics. The table it returns should have four columns: `geo`, `population_total`, `children_per_woman_total_fertility`, and `child_mortality_under_5_per_1000_born`. Each row should contain one unique Alpha-3 country code and three statistics: population, fertility rate, and child mortality for that `year` from the `population`, `fertility` and `child_mortality` tables. Only include rows for which all three statistics are available for the country and year.

In addition, restrict the result to country codes that appears in `big_50`, an array of the 50 most populous countries in 2024. This restriction will speed up computations later in the project.

After you write `stats_for_year`, try calling `stats_for_year` on any year between 1960 and 2024. Try to understand the output of stats_for_year.

Hint: The tests for this question are quite comprehensive, so if you pass the tests, your function is probably correct. However, without calling your function yourself and looking at the output, it will be very difficult to understand any problems you have, so try your best to write the function correctly and check that it works before you rely on the `grader` tests to confirm your work.

Hint: What do all three tables have in common (pay attention to column names)?

Hint: Create additional cells before directly writing the function.

[135]:
```
# We first create a population table that only includes the
# 50 countries with the largest 2024 populations. We focus on
# these 50 countries only so that plotting later will run faster.
big_50 = population.where('time', are.equal_to(2024)).sort("population_total",␣
↪descending=True).take(np.arange(50)).column('geo')
population_of_big_50 = population.where('time', are.above(1959)).where('geo',␣
↪are.contained_in(big_50))

def stats_for_year(year):
    """Return a table of the stats for each country that year."""
    p = population_of_big_50.where('time', are.equal_to(year)).drop('time')
    f = fertility.where('time', are.equal_to(year)).drop('time')
    c = child_mortality.where('time', are.equal_to(year)).drop('time')
    country_stats = p.join("geo", f).join("geo", c)
    return country_stats

stats_for_year(1969)
```

[135]:

geo	population_total	children_per_woman_total_fertility	child_mortality_under_5_per_1000_born
afg	11017409	7.4	308.06
ago	5763685	7.39	275.21
arg	23508711	3.05	72.81
bgd	67294133	6.81	224.1
bra	93045777	5.04	135.74
can	21037618	2.36	22.96
chn	802140332	6.16	118.61
civ	5192221	7.93	251.45
cod	19570445	6.3	249.31
col	20291942	5.51	101.46

… (40 rows omitted)

[136]:
```
grader.check("q1_11")
```

[136]: q1_11 results: All test cases passed!

Question 12. Create a table called `pop_by_decade` with two columns called `decade` and `population`, in this order. It has a row for each year that starts a decade, in increasing order starting with 1960 and ending with 2020. For example, 1960 is the start of the 1960's decade. The `population` column contains the total population of all countries included in the result of `stats_for_year(year)` for the first `year` of the decade. You should see that these countries contain most of the world's population.

Hint: One approach is to define a function `pop_for_year` that computes this total population, then `apply` it to the `decade` column. **Think about how you can use the `stats_for_year` function** from the previous question if you want to implement `pop_for_year`.

This first test is just a sanity check for your helper function if you choose to use it. **You will not lose points for not implementing the function `pop_for_year`**.

Note: The cell where you will generate the `pop_by_decade` table is below the cell where you can choose to define the helper function `pop_for_year`. You should define your `pop_by_decade` table in the cell that starts with the table `decades` being defined.

[137]:
```
def pop_for_year(year):
    """Return the total population for the specified year."""
    return np.sum(stats_for_year(year).column("population_total"))
```

[138]:
```
grader.check("q1_12_0")
```

[138]: q1_12_0 results: All test cases passed!

Now that you've defined your helper function (if you've chosen to do so), define the `pop_by_decade` table.

[139]:
```
decades = Table().with_column('decade', np.arange(1960, 2021, 10))

pop_by_decade = decades.with_columns("population", decades.apply(pop_for_year,␣
↪"decade"))
pop_by_decade.set_format(1, NumberFormatter)
```

[139]:
```
decade | population
1960   | 2,604,997,601
1970   | 3,202,277,698
1980   | 3,863,485,128
1990   | 4,639,963,324
2000   | 5,381,686,829
2010   | 6,107,215,351
```

```
2020    | 6,840,687,359
```

[140]:
```
grader.check("q1_12")
```

[140]:
```
q1_12 results: All test cases passed!
```

The `countries` table describes various characteristics of countries. The `country` column contains the same codes as the `geo` column in each of the other data tables (`population`, `fertility`, and `child_mortality`). The `world_6region` column classifies each country into a region of the world. Run the cell below to inspect the data.

[141]:
```
countries = Table.read_table('countries.csv').where('country', are.
 ↪contained_in(population.group('geo').column('geo')))
countries.select('country', 'name', 'world_6region')
```

[141]:
```
country | name                 | world_6region
afg     | Afghanistan          | south_asia
ago     | Angola               | sub_saharan_africa
alb     | Albania              | europe_central_asia
and     | Andorra              | europe_central_asia
are     | United Arab Emirates | middle_east_north_africa
arg     | Argentina            | america
arm     | Armenia              | europe_central_asia
atg     | Antigua and Barbuda  | america
aus     | Australia            | east_asia_pacific
aut     | Austria              | europe_central_asia
… (187 rows omitted)
```

Question 13. Create a table called `region_counts`. It should contain two columns called `region` and `count`. The `region` column should contain regions of the world, and the `count` column should contain the number of countries in each region that appears in the result of `stats_for_year(2024)`.

For example, one row would have `south_asia` as its `region` value and an integer as its `count` value: the number of large South Asian countries for which we have population, fertility, and child mortality numbers from 2024.

Hint: You may have to relabel a column to name it `region`.

[142]:
```
stats_for_2024 = stats_for_year(2024)
region_counts = stats_for_2024.join("geo", countries, "country").
 ↪group("world_6region").relabeled("world_6region", "region")
region_counts
```

[142]:
```
region                    | count
america                   | 7
east_asia_pacific         | 9
europe_central_asia       | 10
```

```
middle_east_north_africa | 7
south_asia               | 4
sub_saharan_africa       | 13
```

[143]:
```
grader.check("q1_13")
```

[143]:
```
q1_13 results: All test cases passed!
```

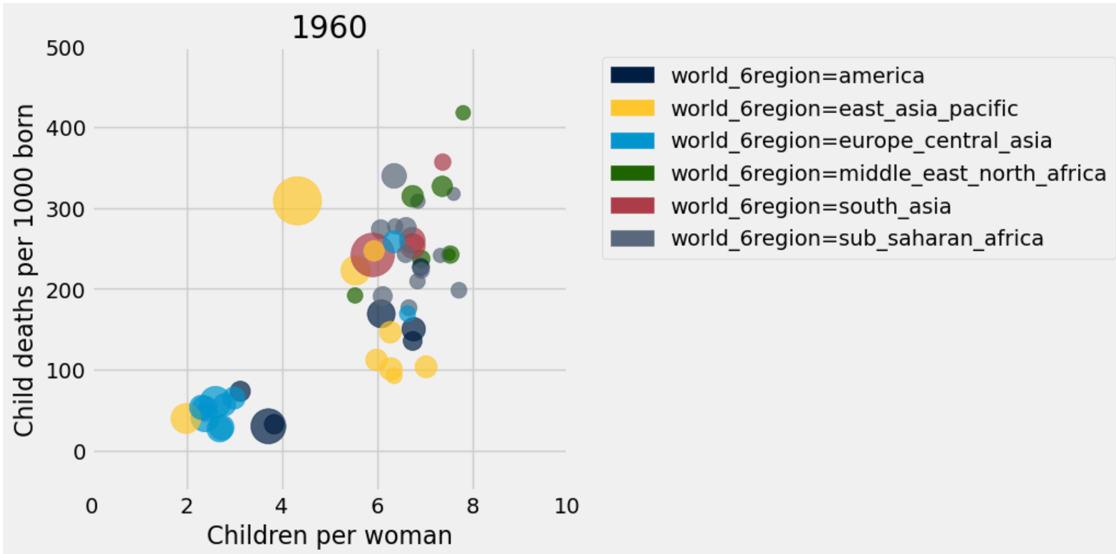
The following scatter diagram compares total fertility rate and child mortality rate for each country in 1960. The area of each dot represents the population of the country, and the color represents its region of the world. Run the cell. Do you think you can identify any of the dots?

[144]:
```
from functools import lru_cache as cache

# This cache annotation makes sure that if the same year
# is passed as an argument twice, the work of computing
# the result is only carried out once.
@cache(None)
def stats_relabeled(year):
    """Relabeled and cached version of stats_for_year."""
    return stats_for_year(year).relabel(2, 'Children per woman').relabel(3,␣
↪'Child deaths per 1000 born')

def fertility_vs_child_mortality(year):
    """Draw a color scatter diagram comparing child mortality and fertility."""
    with_region = stats_relabeled(year).join('geo', countries.select('country',␣
↪'world_6region'), 'country')
    with_region.scatter(2, 3, sizes=1, group=4, s=500)
    plots.xlim(0,10)
    plots.ylim(-50, 500)
    plots.title(year)
    plots.show()

fertility_vs_child_mortality(1960)
```



Question 14. Assign `scatter_statements` to an array of the numbers of each statement below that can be inferred from this scatter diagram for 1960. 1. All countries in `europe_central_asia` had uniformly low fertility rates. 1. The lowest child mortality rate of any country was from an `east_asia_pacific` country. 1. Most countries had a fertility rate above 5. 1. There was an association between child mortality and fertility. 1. The two largest countries by population also had the two highest child mortality rates.

[145]:
```
scatter_statements = make_array(2, 3, 4)
```

[146]:
```
grader.check("q1_14")
```

[146]: q1_14 results: All test cases passed!

The result of the cell below is interactive. Drag the slider to the right to see how countries have changed over time. You'll find that in terms of population growth, the divide between the countries of the global North and global South that existed in the 1960s has shrunk significantly.

This shift in fertility rates is the reason that the global population is expected to grow more slowly in the 21st century than it did in the 19th and 20th centuries. Fertility rates change for reasons that include cultural patterns, better prospects for children surviving to adulthood, and family planning (such as contraception and women's greater control over their reproduction).

Note: Don't worry if a red warning pops up when running the cell below. You'll still be able to run the cell!

[147]:
```
_ = widgets.interact(fertility_vs_child_mortality,
                     year=widgets.IntSlider(min=1960, max=2024, value=1960))
```

```
interactive(children=(IntSlider(value=1960, description='year', max=2024,␣
↪min=1960), Output()), _dom_classes=(…
```

Now is a great time to take a break and watch the same data presented by Hans Rosling in a 2010 TEDx talk with smoother animation and witty commentary.

When we look at population and fertility as data scientists, we need to learn about the experiences of people in real life, not just abstractly as data. We should also recognize that population studies have sometimes had political undercurrents. Those undercurrents have included population control, control of women's reproduction, or fears of shifts between racial groups. To do better as data scientists, we should check our assumptions to avoid unthinkingly reproducing past patterns.

1.4 2. Global Poverty

In 1800, 85% of the world's 1 billion people lived in extreme poverty, defined by the United Nations as "a condition characterized by severe deprivation of basic human needs, including food, safe drinking water, sanitation facilities, health, shelter, education and information." At the time when the data in this project were gathered, a common definition of extreme poverty was a person living on less than \$1.25 a day.

In 2018, the proportion of people living in extreme poverty was estimated to be about 9%. Although the world rate of extreme poverty has declined consistently for hundreds of years, the number of people living in extreme poverty is still over 600 million. The United Nations adopted an ambitious goal: "By 2030, eradicate extreme poverty for all people everywhere."

In this part of the project, we will examine some aspects of global poverty that might affect whether the goal is achievable. The causes of poverty are complex. They include global histories, such as colonialism, as well as factors such as health care, economics, and social inequality in each country.

First, load the population and poverty rate by country and year and the country descriptions. While the `population` table has values for every recent year for many countries, the `poverty` table only includes certain years for each country in which a measurement of the rate of extreme poverty was available.

[148]:
```
population = Table.read_table('population.csv')
countries = Table.read_table('countries.csv').where('country', are.
↪contained_in(population.group('geo').column('geo')))
poverty = Table.read_table('poverty.csv')
poverty.show(3)
```

```
<IPython.core.display.HTML object>
```

Question 1. Assign `latest_poverty` to a three-column table with one row for each country that appears in the `poverty` table. The first column should contain the 3-letter code for the country. The second column should contain the most recent year for which an extreme poverty rate is available for the country. The third column should contain the poverty rate in that year. **Do not change the last line, so that the labels of your table are set correctly.**

Hint: think about how `group` works: it does a sequential search of the table (from top to bottom) and collects values in the array in the order in which they appear, and then applies a function to that array. The `first` function may be helpful, but you are not required to use it.

[149]:
```
def first(values):
    return values.item(0)

latest_poverty = poverty.sort("time", descending=True).group("geo", first)
latest_poverty = latest_poverty.relabeled(0, 'geo').relabeled(1, 'time').
 ↪relabeled(2, 'poverty_percent') # You should *not* change this line.
latest_poverty
```

[149]:
```
geo  | time | poverty_percent
ago  | 2009 | 43.37
alb  | 2012 | 0.46
arg  | 2011 | 1.41
arm  | 2012 | 1.75
aus  | 2003 | 1.36
aut  | 2004 | 0.34
aze  | 2008 | 0.31
bdi  | 2006 | 81.32
bel  | 2000 | 0.5
ben  | 2012 | 51.61
… (135 rows omitted)
```

[150]:
```
grader.check("q2_1")
```

[150]:
```
q2_1 results: All test cases passed!
```

Question 2. Using both `latest_poverty` and `population`, create a four-column table called `recent_poverty_total` with one row for each country in `latest_poverty`. The four columns should have the following labels and contents: 1. `geo` contains the 3-letter country code, 1. `poverty_percent` contains the most recent poverty percent, 1. `population_total` contains the population of the country in 2010, 1. `poverty_total` contains the number of people in poverty **rounded to the nearest integer**, based on the 2010 population and most recent poverty rate.

Hint: You are not required to use `poverty_and_pop`, and you are always welcome to add any additional names.

[151]:
```
poverty_and_pop = latest_poverty.join("geo", population.where("time", are.
 ↪equal_to(2010)), "geo")
poverty_total = (poverty_and_pop.column("poverty_percent") / 100) *␣
 ↪poverty_and_pop.column("population_total")
poverty_total_rounded = np.round(poverty_total)
recent_poverty_total = poverty_and_pop.select("geo", "poverty_percent",␣
 ↪"population_total").with_columns(
    "poverty_total", poverty_total_rounded)
recent_poverty_total
```

[151]:
```
geo  | poverty_percent | population_total | poverty_total
ago  | 43.37           | 23294825         | 1.0103e+07
alb  | 0.46            | 2928722          | 13472
arg  | 1.41            | 41288694         | 582171
arm  | 1.75            | 2931078          | 51294
aus  | 1.36            | 22141581         | 301126
aut  | 0.34            | 8365092          | 28441
aze  | 0.31            | 9146851          | 28355
bdi  | 81.32           | 9376444          | 7.62492e+06
bel  | 0.5             | 10936626         | 54683
ben  | 51.61           | 9797484          | 5.05648e+06
… (135 rows omitted)
```

[152]:
```
grader.check("q2_2")
```

[152]:
```
q2_2 results: All test cases passed!
```

Question 3. Assign the name `poverty_percent` to the known percentage of the world's 2010 population that were living in extreme poverty. Assume that the `poverty_total` numbers in the `recent_poverty_total` table describe **all** people in 2010 living in extreme poverty. You should get a number that is above the 2018 global estimate of 9%, since many country-specific poverty rates are older than 2018.

Hint: The sum of the `population_total` column in the `recent_poverty_total` table is not the world population, because only a subset of the world's countries are included in the `recent_poverty_total` table (only some countries have known poverty rates). Use the `population` table to compute the world's 2010 total population.

Hint: We are computing a percentage (value between 0 and 100), not a proportion (value between 0 and 1).

[153]:
```
poverty_percent = (sum(recent_poverty_total.column("poverty_total")) /␣
 ↪sum(population.where("time", are.equal_to(2010)).
 ↪column("population_total"))) * 100
poverty_percent
```

[153]:
```
14.429159949245513
```

[154]:
```
grader.check("q2_3")
```

[154]:
```
q2_3 results: All test cases passed!
```

The `countries` table includes not only the name and region of countries, but also their positions on the globe.

[155]:
```
countries.select('country', 'name', 'world_4region', 'latitude', 'longitude')
```

[155]:
```
country | name                 | world_4region | latitude | longitude
afg     | Afghanistan          | asia          | 33       | 66
ago     | Angola               | africa        | -12.5    | 18.5
alb     | Albania              | europe        | 41       | 20
and     | Andorra              | europe        | 42.5078  | 1.52109
are     | United Arab Emirates | asia          | 23.75    | 54.5
arg     | Argentina            | americas      | -34      | -64
arm     | Armenia              | europe        | 40.25    | 45
atg     | Antigua and Barbuda  | americas      | 17.05    | -61.8
aus     | Australia            | asia          | -25      | 135
aut     | Austria              | europe        | 47.3333  | 13.3333
… (187 rows omitted)
```

Question 4. Using both `countries` and `recent_poverty_total`, create a five-column table called `poverty_map` with one row for every country in `recent_poverty_total`. The five columns should have the following labels and contents, in this order: 1. `latitude` contains the country's latitude, 1. `longitude` contains the country's longitude, 1. `name` contains the country's name, 1. `region` contains the country's region from the `world_4region` column of `countries`, 1. `poverty_total` contains the country's poverty total.

[156]:
```
poverty_map = recent_poverty_total.join("geo", countries, "country").
↪relabeled("world_4region", "region").select("latitude", "longitude", "name",␣
↪"region", "poverty_total")
poverty_map
```

[156]:
```
latitude | longitude | name       | region   | poverty_total
-12.5    | 18.5      | Angola     | africa   | 1.0103e+07
41       | 20        | Albania    | europe   | 13472
-34      | -64       | Argentina  | americas | 582171
40.25    | 45        | Armenia    | europe   | 51294
-25      | 135       | Australia  | asia     | 301126
47.3333  | 13.3333   | Austria    | europe   | 28441
40.5     | 47.5      | Azerbaijan | europe   | 28355
-3.5     | 30        | Burundi    | africa   | 7.62492e+06
50.75    | 4.5       | Belgium    | europe   | 54683
9.5      | 2.25      | Benin      | africa   | 5.05648e+06
… (135 rows omitted)
```

[157]:
```
grader.check("q2_4")
```

[157]:
```
q2_4 results: All test cases passed!
```

Run the cell below to draw a map of the world in which the areas of circles represent the number of people living in extreme poverty. Double-click on the map to zoom in.

Note: If the cell below isn't loading, you can view the output here

[158]:
```
# It may take a few seconds to generate this map.
colors = {'africa': 'blue', 'europe': 'black', 'asia': 'red', 'americas':␣
↪'green'}
scaled = poverty_map.with_columns(
    'labels', poverty_map.column('name'),
    'colors', poverty_map.apply(colors.get, 'region'),
    'areas', 1e-4 * poverty_map.column('poverty_total')
).drop('name', 'region', 'poverty_total')

Circle.map_table(scaled)
```

[158]:
```
<datascience.maps.Map at 0x7ac5e0d67310>
```

Although people lived in extreme poverty throughout the world in 2010 (with more than 5 million in the United States), the largest numbers were in Asia and Africa.

Question 5. Assign `largest` to a two-column table with the `name` (not the 3-letter code) and `poverty_total` of the 10 countries with the largest number of people living in extreme poverty.

Hint: How can we use `take` and `np.arange` in conjunction with each other?

[159]:
```
largest = poverty_map.sort("poverty_total", descending=True).select("name",␣
↪"poverty_total").take(np.arange(10))
largest.set_format('poverty_total', NumberFormatter)
```

[159]:
```
name             | poverty_total
India            | 293,834,694.00
Nigeria          | 103,368,582.00
China            | 84,607,751.00
Bangladesh       | 65,827,357.00
Congo, Dem. Rep. | 60,143,497.00
Indonesia        | 39,901,462.00
Ethiopia         | 33,309,119.00
Pakistan         | 25,383,055.00
Tanzania         | 19,460,991.00
Madagascar       | 19,448,134.00
```

[160]:
```
grader.check("q2_5")
```

[160]:
```
q2_5 results: All test cases passed!
```

Question 6. It is important to study the absolute number of people living in poverty, not just the percent. The absolute number is an important factor in determining the amount of resources needed to support people living in poverty. In the next two questions you will explore this.

In Question 7, you will be asked to write a function called `poverty_timeline` that takes **the name**

of a country as its argument (not the Alpha-3 country code). It should draw a line plot of the number of people living in poverty in that country with time on the horizontal axis. The line plot should have a point for each row in the poverty table for that country. To compute the population living in poverty from a poverty percentage, multiply by the population of the country **in that year**.

For this question, write out a generalized process for Question 7. Make sure to answer/include the following: - What should this function output? - Additionally, **make a numbered list** of the steps you take within the function body. If you added/edited, say, 5 lines in the function body, then it would be good to see the numbers 1 through 5 describing what you did (i.e. what functions/methods you used) in each line and why.

As a tip, after finishing question 7, we recommend polishing up your description of the steps for this question. This question will be graded for correctness.

This function should return a line plot of a country's total number of impoverished people in each year of the `poverty` table. Firstly, I will use the `country` table to extract the Alpha-3 country code as a string with the corresponding `country` argument in `poverty_timeline`. Secondly, I will filter the `poverty` table to where the `geo` column only contains the string from the first step. Thirdly, I will perform the same filter for the `population` table, and I will add another filter that will only show years that are contained in the `time` column of the `poverty` table. Then, I will join the filtered `poverty` and `population` tables together by `time` and perform any necessary table editing, namely relabeling and dropping columns. Lastly, I will create the final table by adding a column that outputs a country's total number of impoverished people in each year, then I will create a line plot of the final table with the `x_column` as time and the `y_column` as the total number of people impoverished.

Question 7. Now, we'll actually write the function called `poverty_timeline`. Recall that `poverty_timeline` takes **the name of a country** as its argument (not the Alpha-3 country code). It should draw a line plot of the number of people living in poverty in that country with time on the horizontal axis. The line plot should have a point for each row in the `poverty` table for that country. To compute the population living in poverty from a poverty percentage, multiply by the population of the country **in that year**.

Note: You **should not** return anything from your function. Simply call `plots.show()` at the end of your function body.

Hint 1: This question is long. Feel free to create cells and experiment. You can create cells by going to the toolbar and hitting the `+` button.

Hint 2: Consider using `join` in your code.

Feel free to use the markdown cell below to plan out your answer, but you needn't fill it in.

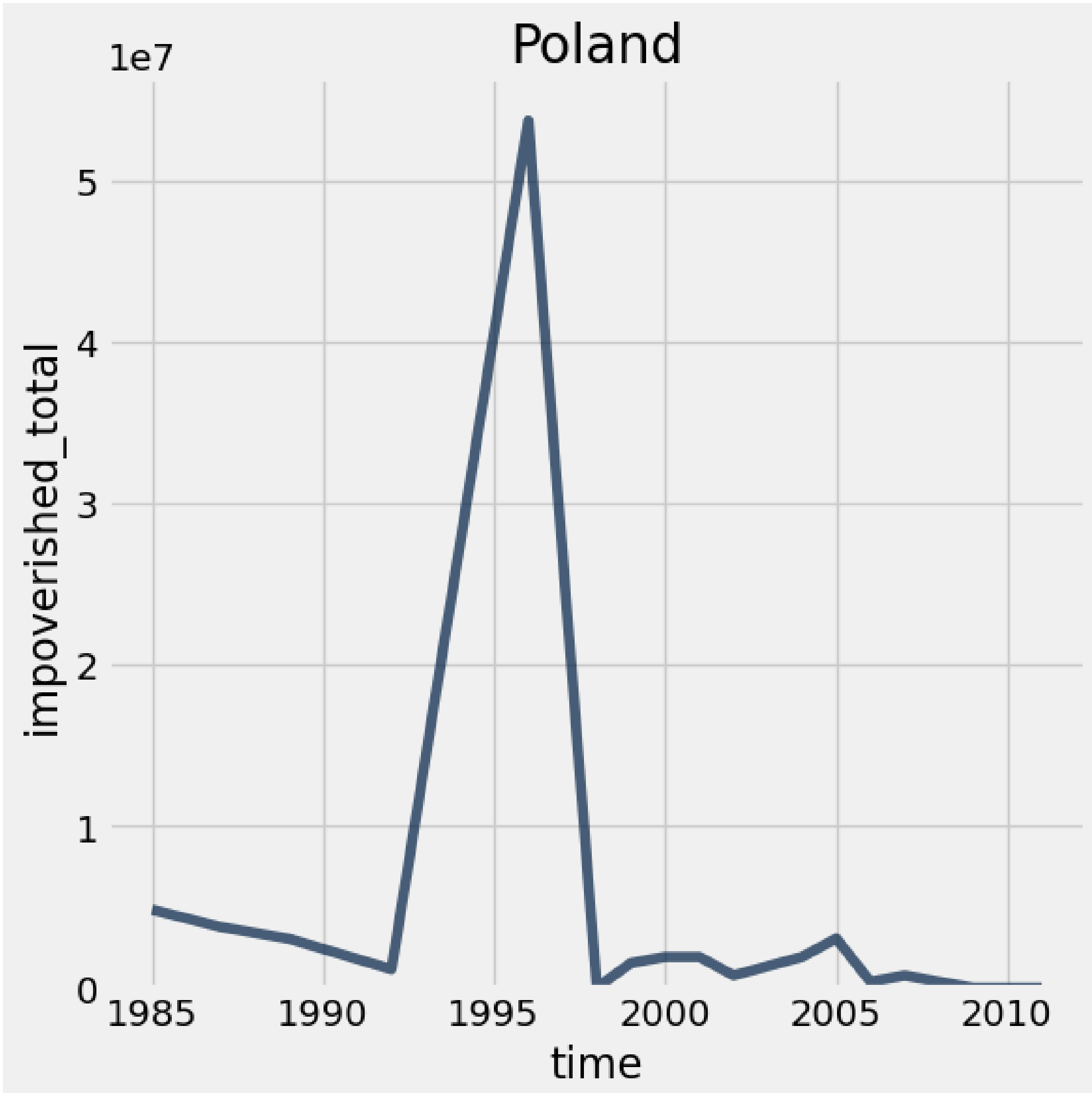
Type your answer here, replacing this text.

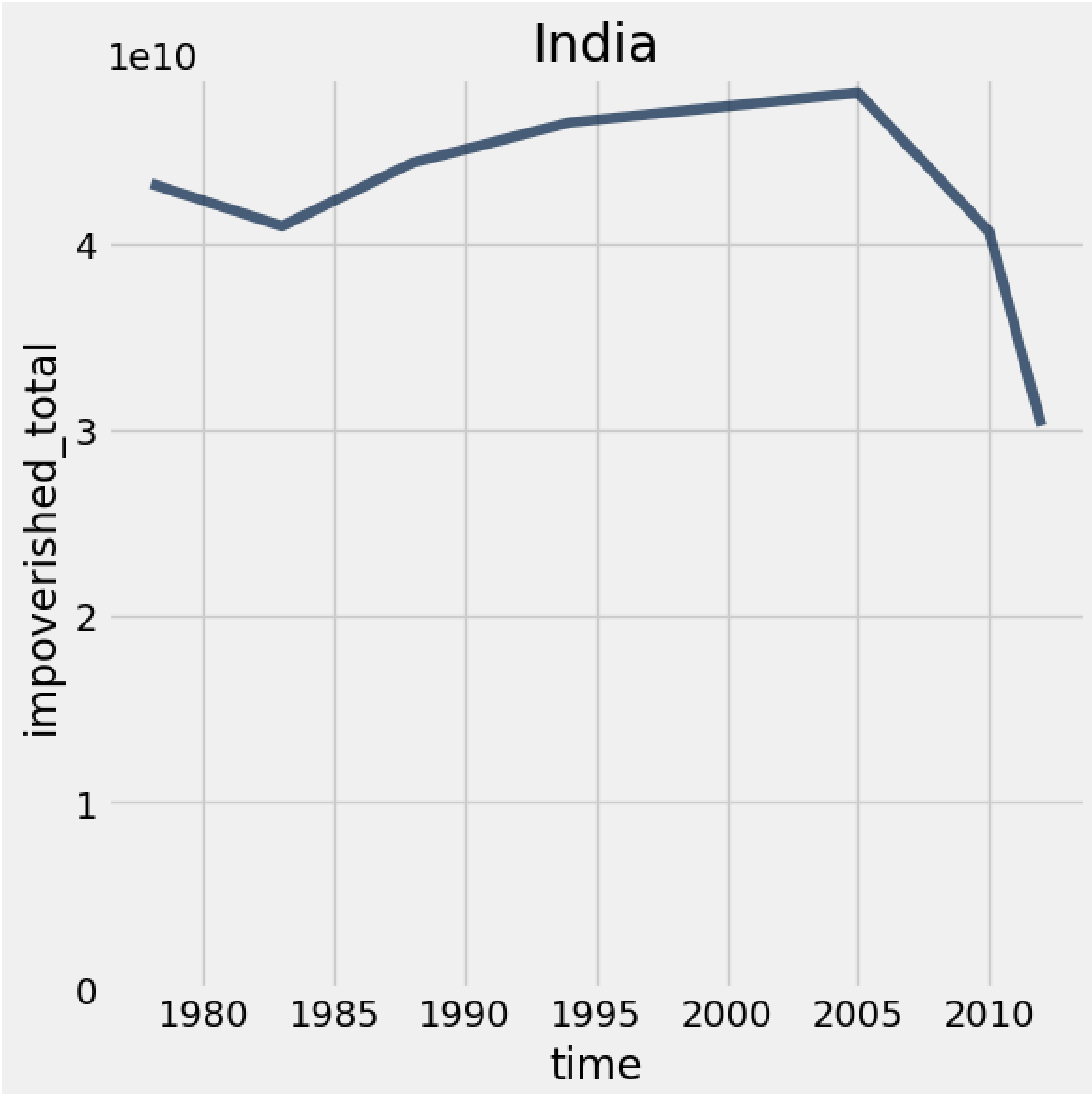
[161]:
```
def poverty_timeline(country):
    '''Draw a timeline of people living in extreme poverty in a country.'''
    geo = countries.where("name", are.equal_to(country)).column("country").
 ↪item(0)
    # This solution will take multiple lines of code. Use as many as you need
```

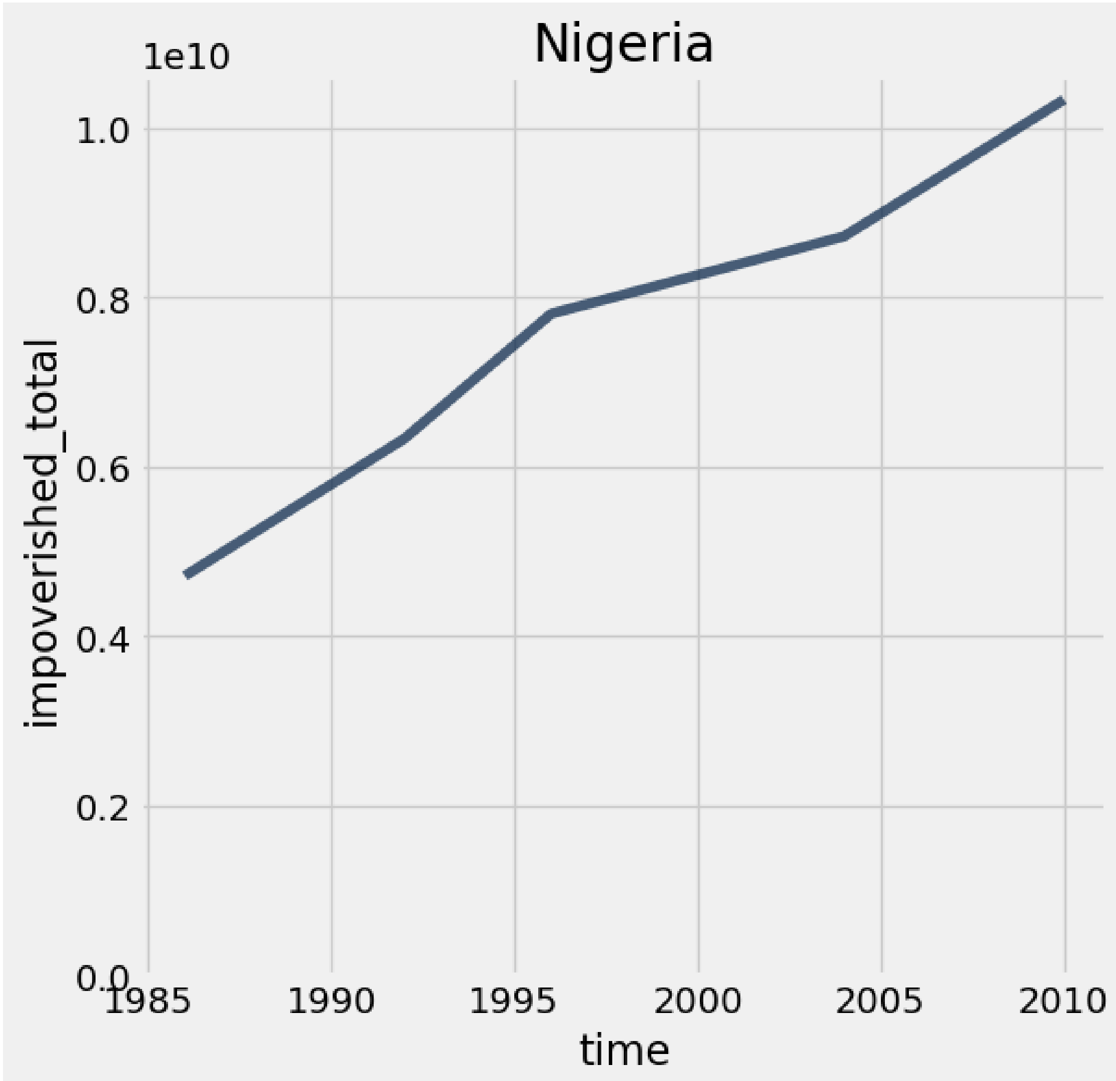
```
    poverty_filter = poverty.where("geo", are.equal_to(geo))
    population_filter = population.where("geo", are.equal_to(geo)).
 ↪where("time", are.contained_in(poverty_filter.column("time")))
    pov_pop_join = poverty_filter.join("time", population_filter)
    pp_join_adjusted = pov_pop_join.
 ↪relabeled("extreme_poverty_percent_people_below_125_a_day",␣
 ↪"poverty_percentage").drop("geo_2")
    pov_timeline_table = pp_join_adjusted.with_columns(
        "impoverished_total", pp_join_adjusted.column("poverty_percentage") *␣
 ↪pp_join_adjusted.column("population_total"))
    pov_timeline_table.plot("time", "impoverished_total")
    # Don't change anything below this line.
    plots.title(country)
    plots.ylim(bottom=0)
    plots.show() # This should be the last line of your function.
```

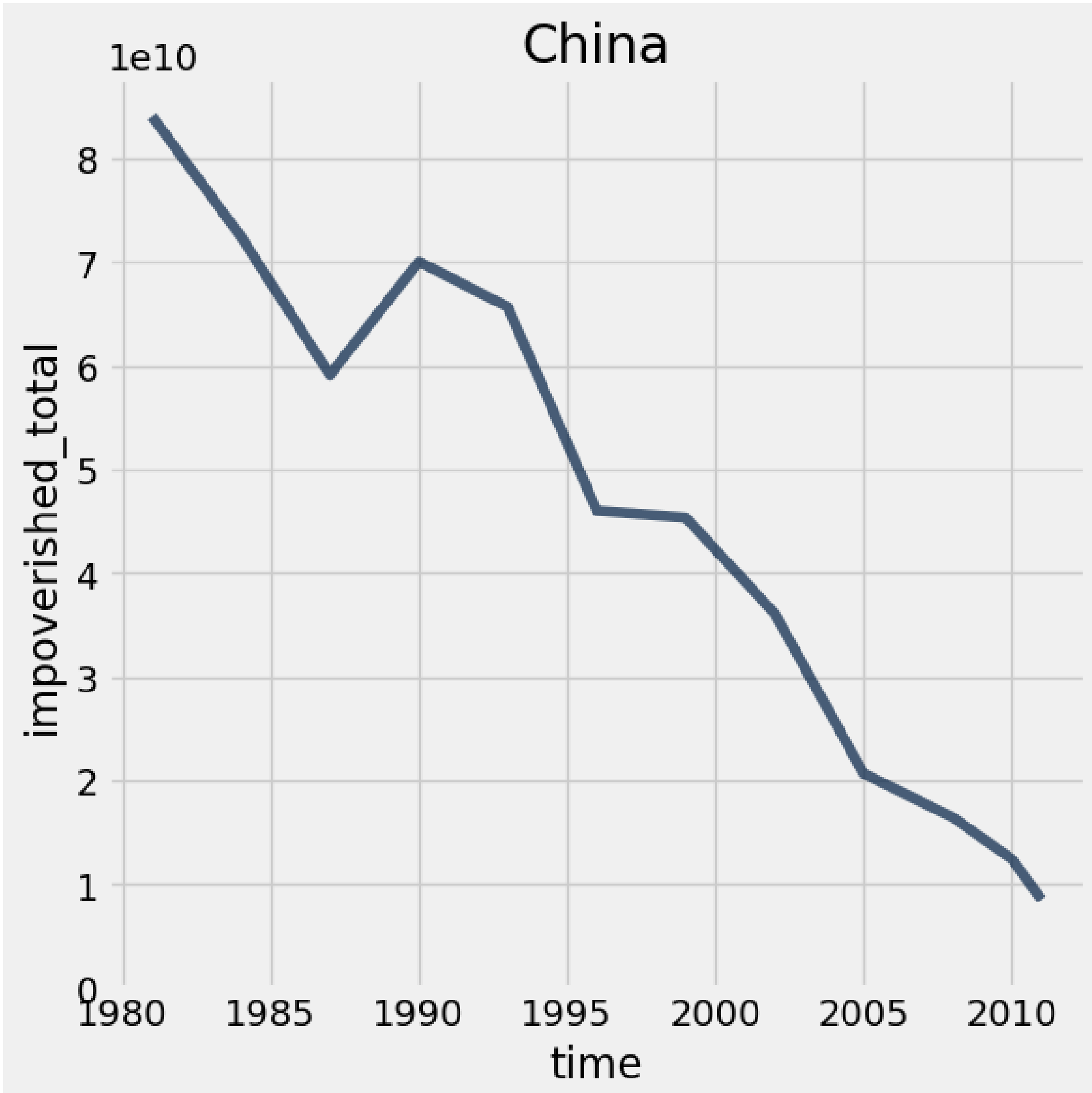
[162]:

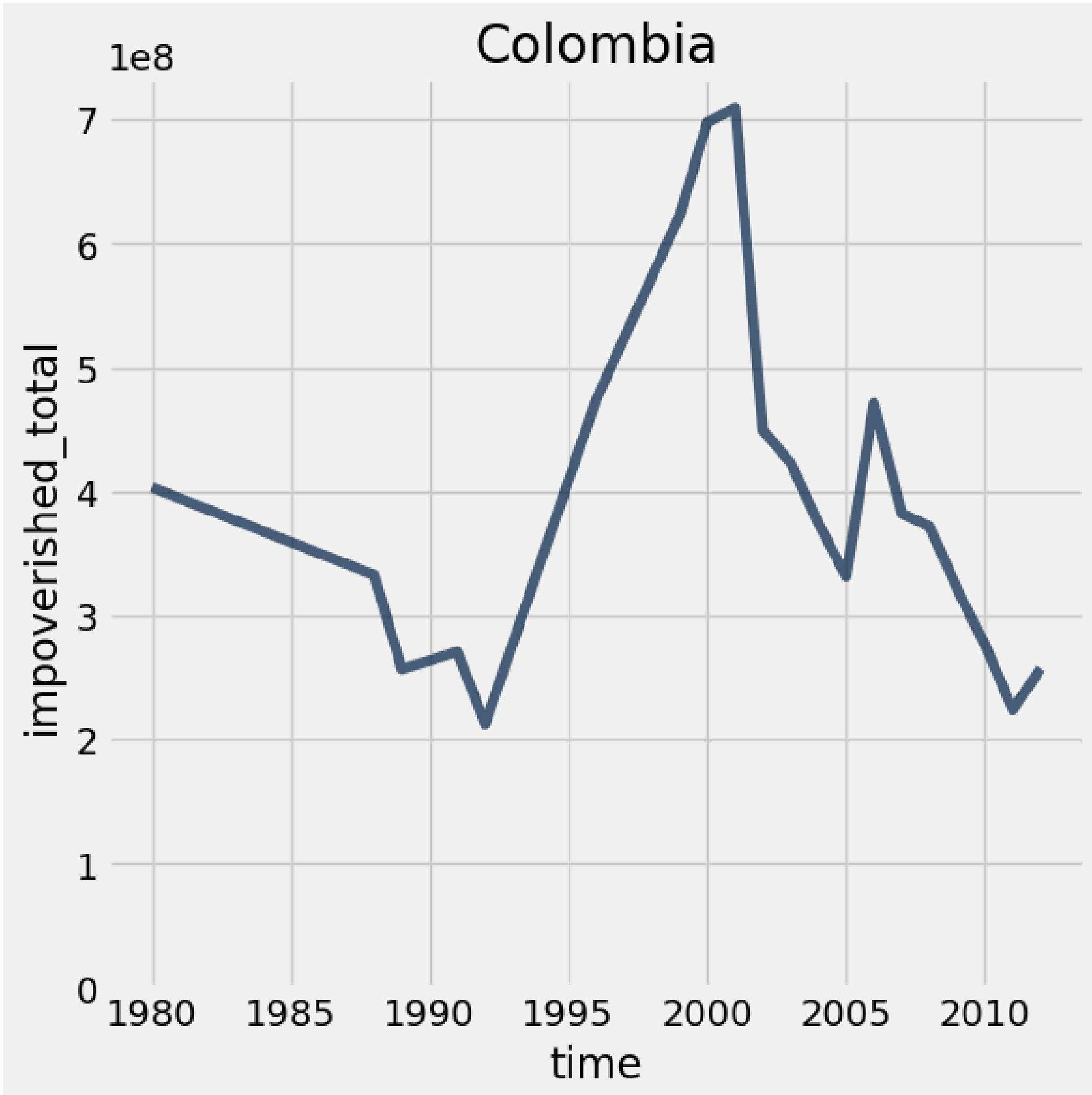
```
poverty_timeline('Poland')
poverty_timeline('India')
poverty_timeline('Nigeria')
poverty_timeline('China')
poverty_timeline('Colombia')
poverty_timeline('United States')
```

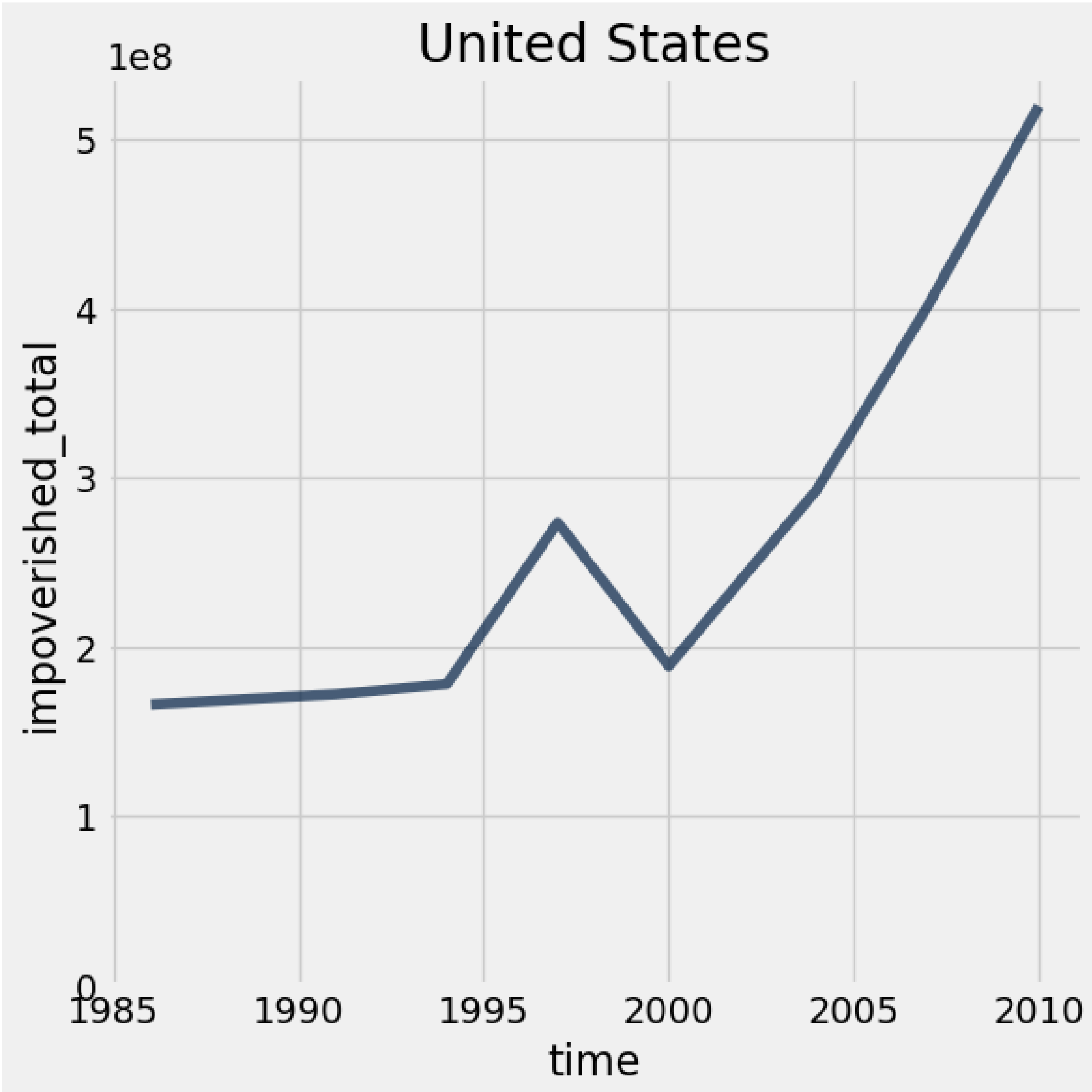

Poland
1e7
5
4
3
2
1
0
impoverished_total
1985
1990
1995
2000
2005
2010
time


India
1e10
4
3
2
1
0
impoverished_total
1980
1985
1990
1995
2000
2005
2010
time


Nigeria
1e10
1.0
0.8
0.6
0.4
0.2
0.0
impoverished_total
1985
1990
1995
2000
2005
2010
time


China
1e10
impoverished_total
0
1
2
3
4
5
6
7
8
1980
1985
1990
1995
2000
2005
2010
time


Colombia
1e8
7
6
5
4
3
2
1
0
impoverished_total
1980
1985
1990
1995
2000
2005
2010
time



Although the number of people living in extreme poverty increased in some countries including Nigeria and the United States, the decreases in other countries, most notably the massive decreases in China and India, have shaped the overall trend that extreme poverty is decreasing worldwide, both in percentage and in absolute number.

To learn more, watch Hans Rosling in a 2015 film about the UN goal of eradicating extreme poverty from the world.

Below, we've also added an interactive dropdown menu for you to visualize `poverty_timeline` graphs for other countries. Note that each dropdown menu selection may take a few seconds to run.

[163]:
```
# Just run this cell
```

```
all_countries = poverty_map.column('name')
_ = widgets.interact(poverty_timeline, country=list(all_countries))
```

```
interactive(children=(Dropdown(description='country', options=('Angola',␣
↪'Albania', 'Argentina', 'Armenia', 'A…
```

Panda wants to tell you, you're finished! Congratulations on discovering many important facts about global poverty and demonstrating your mastery of table manipulation and data visualization. Time to submit.

Remember to add your project partner to your submission on Gradescope! Only one partner should submit to Gradescope.

1.5 Submission

Below, you will see two cells. Running the first cell will automatically generate a PDF of all questions that need to be manually graded, and running the second cell will automatically generate a zip with your autograded answers. You are responsible for submitting both the coding portion (the zip) and the written portion (the PDF) to their respective Gradescope portals. **Please save before exporting!**

> **Important: You must correctly assign the pages of your PDF after you submit to the correct gradescope assignment. If your pages are not correctly assigned and/or not in the correct PDF format by the deadline, we reserve the right to award no points for your written work.**

If there are issues with automatically generating the PDF in the first cell, you can try downloading the notebook as a PDF by colicking on `File -> Save and Export Notebook As... -> PDF`. If that doesn't work either, you can manually take screenshots of your answers to the manually graded questions and submit those. Either way, **you are responsible for ensuring your submision follows our requirements, we will NOT be granting regrade requests for submissions that don't follow instructions.**

You must submit the PDF generated via one of these methods, we will not accept screenshots or Word documents.

[164]:
```
from otter.export import export_notebook
from os import path
from IPython.display import display, HTML
name = 'project1'
export_notebook(f"{name}.ipynb", filtering=True, pagebreaks=True)
if(path.exists(f'{name}.pdf')):
    display(HTML(f"Download your PDF <a href='{name}.pdf' download>here</a>."))
else:
    print("\n Pdf generation failed, please try the other methods described␣
↪above")
```

```
<IPython.core.display.HTML object>
```

1.6 Submission

Make sure you have run all cells in your notebook in order before running the cell below, so that all images/graphs appear in the output. The cell below will generate a zip file for you to submit. **Please save before exporting!**

[165]:
```
# Save your notebook first, then run this cell to export your submission.
grader.export(pdf=False, run_tests=True)
```

```
Running your submission against local test cases…



Your submission received the following results when run against available test
cases:

    q0 results: All test cases passed!

    q1_1 results: All test cases passed!

    q1_2 results: All test cases passed!

    q1_5 results: All test cases passed!

    q1_7 results: All test cases passed!

    q1_9 results: All test cases passed!

    q1_11 results: All test cases passed!

    q1_12_0 results: All test cases passed!

    q1_12 results: All test cases passed!

    q1_13 results: All test cases passed!

    q1_14 results: All test cases passed!

    q2_1 results: All test cases passed!

    q2_2 results: All test cases passed!

    q2_3 results: All test cases passed!

    q2_4 results: All test cases passed!

    q2_5 results: All test cases passed!
<IPython.core.display.HTML object>
```