1 Lecture 3b: Source code for plots from Lecture 3a + introduction to Seaborn and Plotly libraries

Data Visualization · 1-DAV-105

Lecture by Broňa Brejová

This notebook contains the source code for all the plots shown in the first part of the lecture. These plots are created mostly using three plotting libraries: Matplotlib, Seaborn, and Plotly. Basics of Matplotlib were discussed in Lecture 1a, Plotly was briefly introduced in Lecture 1c.

1.1 Seaborn library

- Seaborn library is an extension of Matplotlib.
- Seaborn is more convenient for many types of plots; we will use it for more complex scatter plots and line plots, for bar plots, strip plots, histograms and heatmaps.
- In Seaborn functions, a whole DataFrame can be added using option `data=`. DataFrame column names are then used as `x`, `y`, `hue` (color), `col` (one of subfigures).
- Seaborn creates Matplotlib objects (e.g. figure, axes) which can be then modified using Matplotlib methods.
- The first example of this library is in section Categorical variable via color.

1.2 Plotly library for interactive plots

- Another popular library is Plotly.
- It provides some additional plot types and all plots are interactive.
- For example, in the scatter plot, we can find information about each dot by hovering a mouse over it.
- We can also zoom into parts of the plot by selecting a rectangle.
- A menu with additional options appears in the top right corner of the plot.
- Plotly is also used the first time in section Categorical variable via color.

1.3 Used libraries

[1]:
```
import numpy as np
import pandas as pd
from IPython.display import Markdown
import matplotlib.pyplot as plt
import seaborn as sns
import plotly.express as px
```

1.4 Importing World Bank data

Country indicators from World Bank, https://databank.worldbank.org/home under CC BY 4.0 license.

Country population, surface area in km squared, GDP per capita (current US$), life expectancy at birth (years), fertility rate (births per woman); in years 2000, 2010, 2020.

[2]:
```python
url = 'https://bbrejova.github.io/viz/data/World_bank.csv'
countries = pd.read_csv(url).set_index('Country')
display(countries)
```

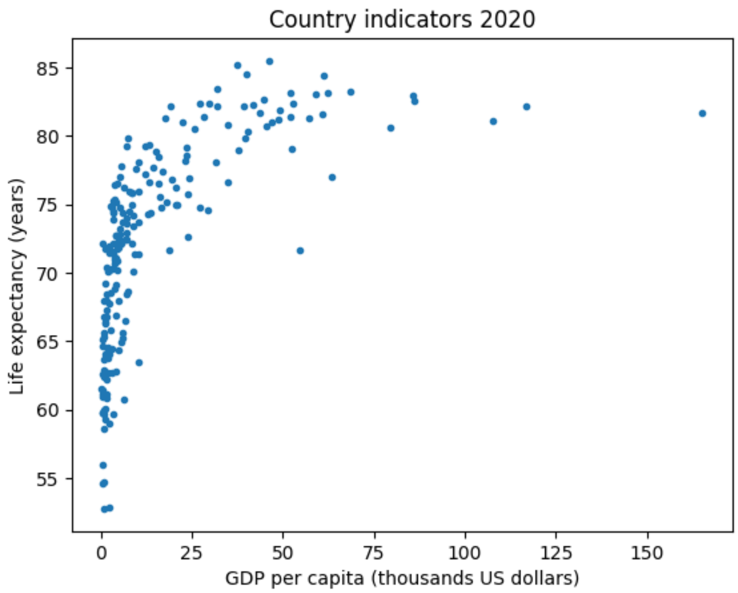
```
                  ISO3                      Region         Income Group  \
Country
Afghanistan        AFG                  South Asia           Low income
Albania            ALB       Europe & Central Asia  Upper middle income
Algeria            DZA  Middle East & North Africa  Lower middle income
American Samoa     ASM         East Asia & Pacific          High income
Andorra            AND       Europe & Central Asia          High income
…                  …                         …                    …
Virgin Islands     VIR   Latin America & Caribbean          High income
West Bank and Gaza PSE  Middle East & North Africa  Upper middle income
Yemen              YEM  Middle East & North Africa           Low income
Zambia             ZMB          Sub-Saharan Africa  Lower middle income
Zimbabwe           ZWE          Sub-Saharan Africa  Lower middle income

                    Population2000  Population2010  Population2020       Area  \
Country
Afghanistan             19542983.0      28189672.0      38972231.0   652860.0
Albania                  3089026.0       2913021.0       2837849.0    28750.0
Algeria                 30774621.0      35856344.0      43451666.0  2381741.0
American Samoa             58229.0         54849.0         46189.0      200.0
Andorra                    66097.0         71519.0         77699.0      470.0
…                              …             …               …         …
Virgin Islands            108642.0        108356.0        106291.0      350.0
West Bank and Gaza       2922153.0       3786161.0       4803269.0     6020.0
Yemen                   18628701.0      24743945.0      32284046.0   527970.0
Zambia                   9891135.0      13792087.0      18927715.0   752610.0
Zimbabwe                11834676.0      12839770.0      15669667.0   390760.0

                         GDP2000       GDP2010       GDP2020  Expectancy2000  \
Country
Afghanistan                  NaN    562.499219    512.055098       55.298000
Albania              1126.683340   4094.349686   5343.037704       75.404000
Algeria              1780.376063   4495.921476   3354.153164       70.478000
American Samoa               NaN  10446.863206  15609.777220             NaN
Andorra             21620.465102  48237.890541  37207.238871             NaN
…                            …           …            …             …
Virgin Islands               NaN  39905.128418  39411.045254       76.619512
West Bank and Gaza   1476.171850   2557.075624   3233.568638       70.388000
Yemen                 519.591639   1249.063085    578.512010       62.588000
Zambia                364.026145   1469.361450    956.831729       45.231000
Zimbabwe              565.284390    937.840340   1372.696674       44.686000

                    Expectancy2010  Expectancy2020  Fertility2000  \
```

```
Country
Afghanistan            60.851000      62.575000          7.534
Albania                77.936000      76.989000          2.231
Algeria                73.808000      74.453000          2.566
American Samoa               NaN            NaN            NaN
Andorra                      NaN            NaN            NaN
…                            …              …          …
Virgin Islands         77.865854      79.819512          2.060
West Bank and Gaza     73.004000      74.403000          5.443
Yemen                  67.280000      64.650000          6.318
Zambia                 56.799000      62.380000          5.926
Zimbabwe               50.652000      61.124000          3.974

                    Fertility2010  Fertility2020
Country
Afghanistan                 6.099          4.750
Albania                     1.656          1.400
Algeria                     2.843          2.942
American Samoa                NaN            NaN
Andorra                     1.270            NaN
…                           …              …
Virgin Islands              2.300          2.030
West Bank and Gaza          4.383          3.570
Yemen                       4.855          3.886
Zambia                      5.363          4.379
Zimbabwe                    4.025          3.545

[217 rows x 16 columns]
```

1.5 A simple scatterplot

To create a simple scatterplot, commands from the previous lectures suffice. Note that we divide GDP by 1000 and add this information to the axis title. This makes the axis easier to read.

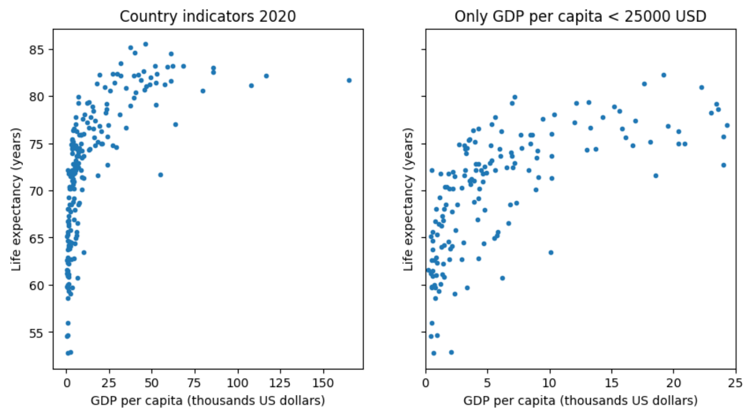
[3]:
```
figure, axes = plt.subplots()
axes.plot(countries.GDP2020 / 1000, countries.Expectancy2020, '.')
axes.set_xlabel('GDP per capita (thousands US dollars)')
axes.set_ylabel('Life expectancy (years)')
axes.set_title('Country indicators 2020')
pass
```



1.6 Zooming in

Limits on x axis are set using `set_xlim` method in order to zoom in on countries with lower GDP.

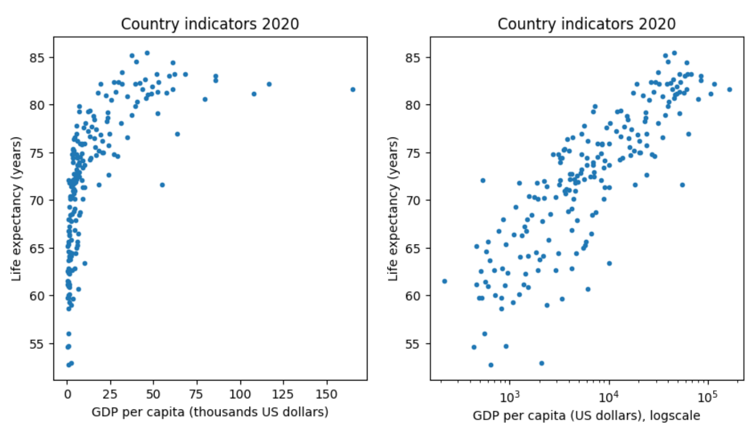
[4]:
```
# create two subplots
figure, axes = plt.subplots(1, 2, figsize=(10, 5), sharey=True)

# the left subplot - full range of data
axes[0].plot(countries.GDP2020 / 1000, countries.Expectancy2020, '.')
axes[0].set_xlabel('GDP per capita (thousands US dollars)')
axes[0].set_ylabel('Life expectancy (years)')
axes[0].set_title('Country indicators 2020')

# the right subplot - smaller values of GDP
axes[1].plot(countries.GDP2020 / 1000, countries.Expectancy2020, '.')
axes[1].set_xlabel('GDP per capita (thousands US dollars)')
axes[1].set_ylabel('Life expectancy (years)')
axes[1].set_title('Only GDP per capita < 25000 USD')
axes[1].set_xlim(0, 25)
pass
```



1.7 Log-scale plot

In this plot, the log-scale on the x-axis is switched on by `semilogx` method; similarly there is `semilogy` for the y-axis and `loglog` for both axes.

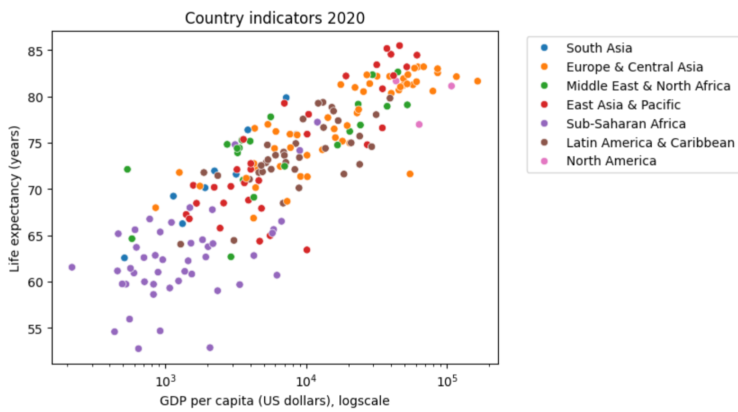
[5]:
```
figure, axes = plt.subplots(1, 2, figsize=(10, 5))

# linear scale plot
axes[0].plot(countries.GDP2020 / 1000, countries.Expectancy2020, '.')
axes[0].set_xlabel('GDP per capita (thousands US dollars)')
axes[0].set_ylabel('Life expectancy (years)')
axes[0].set_title('Country indicators 2020')

# log scale plot
axes[1].plot(countries.GDP2020, countries.Expectancy2020, '.')
axes[1].set_xlabel('GDP per capita (US dollars), logscale')
axes[1].set_ylabel('Life expectancy (years)')
axes[1].set_title('Country indicators 2020')
axes[1].semilogx()
pass
```



1.8 Categorical variable via color

Here we color countries by their region. Seaborn function scatterplot can do this easily via `hue` parameter. This function returns Matplotlib axes which can be then modified by familiar methods such as `set_xlabel`.

[6]:
```
# create plot using Seaborn
axes = sns.scatterplot(data=countries, x='GDP2020', y='Expectancy2020',
                       hue='Region')
# set plot properties using methods from Matplotlib
axes.set_xlabel('GDP per capita (US dollars), logscale')
axes.set_ylabel('Life expectancy (years)')
axes.set_title('Country indicators 2020')
axes.semilogx()
# place legend outside the plot:
axes.legend(bbox_to_anchor=(1.05, 1), loc=2)
pass
```



- The same plot in Plotly is even easier and interactive.
- Both Plotly and Seaborn automatically label axes with column names, such as `GDP2020`.
- Here we override such automated labels with longer ones using a dictionary `fig_labels`.

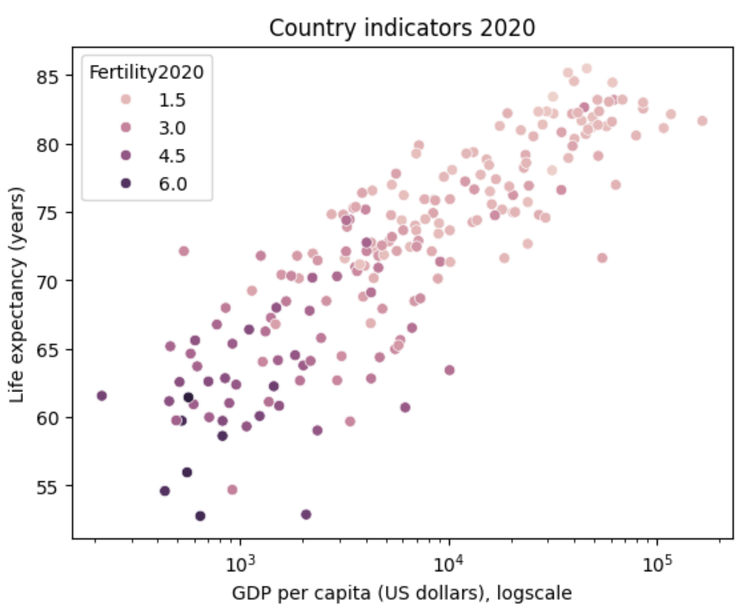
[7]:
```
# we want to use index (country name) in the figure for tooltip info
# therefore we create a temporary table with column Country instead of index
temp_table = countries.reset_index()
# how to rename automated axis labels
fig_labels = {'GDP2020':'GDP per capita (US dollars), logscale',
              'Expectancy2020':'Life expectancy (years)'}
# create Plotly plot, add countyr name to tooltip data
fig = px.scatter(data_frame=temp_table,
                 x="GDP2020", y="Expectancy2020", color="Region",
```

```
                      hover_data=['Country'], log_x=True,
                      labels = fig_labels)
fig.show()
```

1.9 Numerical variable via color

Seaborn automatically detects if the column used as `hue` is a categorical or numerical variable. In the previous graph, regions were used as `hue` and Seaborn chose a color palette with a different color for each category. Here we have a numerical variable so a continuous palette with different shades of pink and purple is used by default. We will discuss color palettes later in the course.

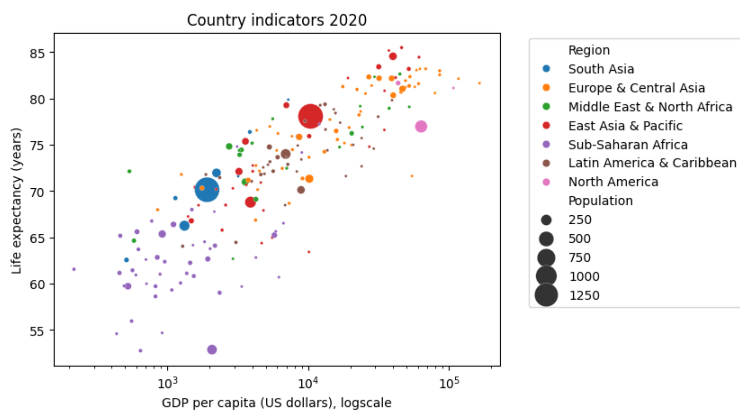
[8]:
```
axes = sns.scatterplot(data=countries, x='GDP2020', y='Expectancy2020',
                       hue='Fertility2020')
axes.set_xlabel('GDP per capita (US dollars), logscale')
axes.set_ylabel('Life expectancy (years)')
axes.set_title('Country indicators 2020')
axes.semilogx()
pass
```



1.10 Numerical variable as point size

We will now use the population of each country as the size of each point (also called bubble), and we will color countries by regions. Sizing points according to the values in a specified table column is again simple to do in Seaborn using paremeter `size` in `sns.scatterplot`. Parameter `sizes` sets the minimum and maximum point size to be used. For simplicity, population in millions is added as a new column to `countries`.

[9]:
```python
# add a column representing population in millions to table countries
countries['Population'] = countries['Population2020'] / 1e6
# create the plot
axes = sns.scatterplot(data=countries,
                       x='GDP2020', y='Expectancy2020', hue='Region',␣
 ↪size='Population',
                       sizes=(5, 400))
# set various plot properties
axes.set_xlabel('GDP per capita (US dollars), logscale')
axes.set_ylabel('Life expectancy (years)')
axes.set_title('Country indicators 2020')
axes.semilogx()
axes.legend(bbox_to_anchor=(1.05, 1), loc=2)
pass
```

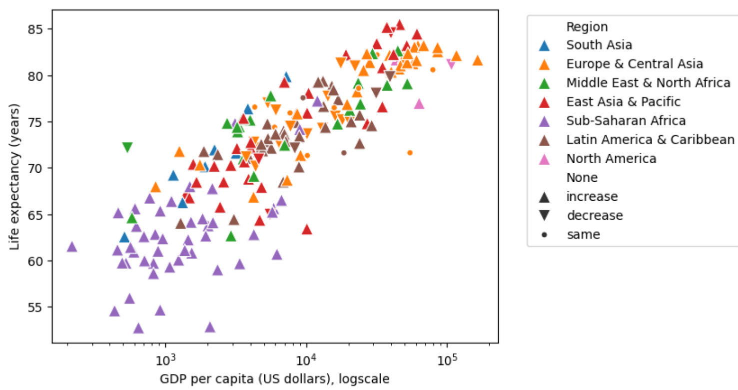


1.11 Categorical variable as marker type

- We add a new column named `Population change` with categories `increase`, `decrease` and `same` depedning on how the population of a country changed between 2010 and 2020. Category `same` is applied to countries with population change less then 1% in either direction.
- This column is created using `apply` command, which applies a function (here a lambda expression) to `diff` Series containing relative change in population.
- This column is then used as argument `style` in `sns.scatterplot`. Size of markers is set to 100 (more than default) by argument `s`. Particular markers are selected by `markers` argument.
- Note that in the `scatterplot` we use both columns of `countries` table and separate Series.

[10]:
```python
# compute relative differences in population between years 2010 and 2020
diff = (countries.Population2020 - countries.Population2010) / countries.
 ↪Population2010
# new series with values 'increase', 'decrease' and 'same'
diff_class = diff.apply(lambda x : 'decrease' if x < -0.01
                        else 'increase' if x > 0.01 else 'same')
```

```python
# create plot
axes = sns.scatterplot(data=countries,
                       x='GDP2020', y='Expectancy2020', hue='Region',
                       style=diff_class, s=100,
                       markers={'increase':'^', 'decrease':'v', 'same':'.'})
# plot settings
axes.semilogx()
axes.set_xlabel('GDP per capita (US dollars), logscale')
axes.set_ylabel('Life expectancy (years)')
axes.legend(bbox_to_anchor=(1.05, 1), loc=2)
pass
```



1.12 Importing Gapminder life expectancy

We import life expectancy data provided free by the Gapminder foundation under the CC-BY license. The data set gives for each year and each country an estimate of how may years would newborn babies live on average if the trends in mortality of different age groups that were prevailing in the year of their birth would prevail through their entire life.

[11]:
```python
url="https://bbrejova.github.io/viz/data/life_expectancy_years.csv"
life_exp = pd.read_csv(url, index_col=0)
life_exp_years = life_exp.iloc[:, 1:]
display(life_exp)
```

	ISO3	1900	1901	1902	1903	1904	1905	1906	1907	\
Country										
Afghanistan	AFG	29.4	29.5	29.5	29.6	29.7	29.7	29.8	29.9	
Albania	ALB	35.4	35.4	35.4	35.4	35.4	35.4	35.4	35.4	
Algeria	DZA	30.2	30.3	30.4	31.4	25.4	28.1	29.6	29.5	
Angola	AGO	29.0	29.1	29.2	29.3	29.3	29.4	29.4	29.5	
Antigua and Barbuda	ATG	33.8	33.8	33.8	33.8	33.8	33.8	33.8	33.8	
…	…	…	…	…	…	…	…	…	…	
Venezuela	VEN	32.4	32.4	32.4	32.4	32.4	32.4	32.5	32.5	
Vietnam	VNM	31.2	31.1	31.1	31.1	31.1	31.0	31.0	31.0	

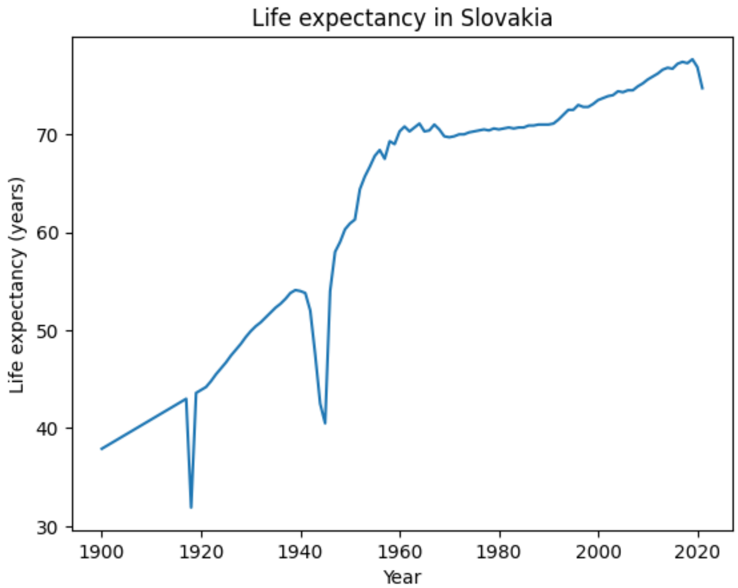
```
Yemen                YEM  23.5  23.5  23.5  23.5  23.5  23.6  23.6  23.6
Zambia               ZMB  33.6  33.6  33.6  33.7  33.7  33.8  33.8  33.8
Zimbabwe             ZWE  34.1  34.1  34.1  34.1  34.1  34.1  34.1  34.1

                     1908  …  2012  2013  2014  2015  2016  2017    2018  \
Country                    …
Afghanistan          29.9  …  60.8  61.3  61.2  61.2  61.2  63.4  63.081
Albania              35.4  …  77.8  77.9  77.9  78.0  78.1  78.2  79.184
Algeria              29.5  …  76.8  76.9  77.0  77.1  77.4  77.7  76.066
Angola               29.6  …  61.3  61.9  62.8  63.3  63.8  64.2  62.144
Antigua and Barbuda  33.8  …  76.7  76.8  76.8  76.9  77.0  77.0  78.511
…                     …  …    …    …    …    …    …    …       …
Venezuela            32.5  …  75.2  75.2  75.0  75.0  75.3  75.3  71.979
Vietnam              30.9  …  73.8  74.0  74.1  74.3  74.4  74.5  73.976
Yemen                23.6  …  68.3  68.9  69.0  68.6  68.1  68.1  64.575
Zambia               33.9  …  58.8  60.0  61.1  62.0  62.8  63.2  62.342
Zimbabwe             34.2  …  54.9  56.8  58.5  59.6  60.5  61.4  61.414

                       2019    2020    2021
Country
Afghanistan          63.565  62.575  61.982
Albania              79.282  76.989  76.463
Algeria              76.474  74.453  76.377
Angola               62.448  62.261  61.643
Antigua and Barbuda  78.691  78.841  78.497
…                       …       …       …
Venezuela            72.161  71.095  70.554
Vietnam              74.093  75.378  73.618
Yemen                65.092  64.650  63.753
Zambia               62.793  62.380  61.223
Zimbabwe             61.292  61.124  59.253

[184 rows x 123 columns]
```

1.13 A simple line graph

Here we use `plot` from matplotlib to plot life expectancy over the years for Slovakia. Years are column names which need to be converted from string to integer using Python list comprehension.

[12]:
```python
# list of numerical years from column names
years = [int(x) for x in life_exp_years.columns]
# simple plot for one row of the table
figure, axes = plt.subplots()
axes.plot(years, life_exp_years.loc['Slovak Republic'])
# plot settings
axes.set_xlabel('Year')
axes.set_ylabel('Life expectancy (years)')
axes.set_title('Life expectancy in Slovakia')
```

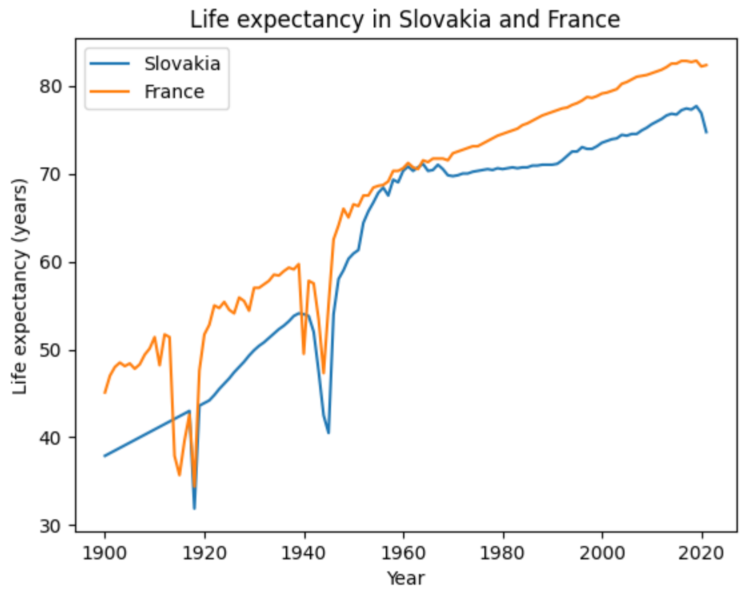
```
pass
```



1.14 A line graph with multiple lines

Here we plot two lines, each by a separate call to `plot`. Each line has a label to show in the legend.

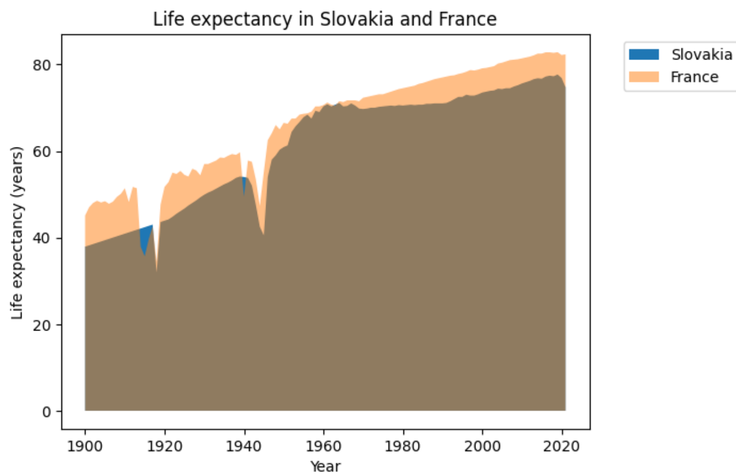
[13]:
```
figure, axes = plt.subplots()
# plot two lines
axes.plot(years, life_exp_years.loc['Slovak Republic'], label='Slovakia')
axes.plot(years, life_exp_years.loc['France'], label='France')
# plot settings
axes.set_xlabel('Year')
axes.set_ylabel('Life expectancy (years)')
axes.set_title('Life expectancy in Slovakia and France')
axes.legend()
pass
```



1.15 Area graph

Here we fill in the area between x-axis (value 0) and a table row using `fill_between` method. France is plotted on top and is set to be semi-transparent using `alpha=0.5`.

[14]:
```
figure, axes = plt.subplots()
# two filled areas, the second is semi-transparent
axes.fill_between(years, 0, life_exp_years.loc['Slovak Republic'],␣
 ↪label='Slovakia')
axes.fill_between(years, 0, life_exp_years.loc['France'], label='France',␣
 ↪alpha=0.5)
# plot settings
axes.set_xlabel('Year')
axes.set_ylabel('Life expectancy (years)')
axes.set_title('Life expectancy in Slovakia and France')
axes.legend(bbox_to_anchor=(1.05, 1), loc=2)
pass
```



1.16 Line graph with many lines

- Here we want to plot lines for all countries alphabetically between Si and Sz and having at least million inhabitants.
- First we select such countries from `countries` to table `selection`.
- Using `intersection`, we get only countries from our selection that are also in Gapminder table (`life_exp`).
- Part of the Gapminder table for these coutnries is then stored as `life_exp_sel`.

[15]:
```
selection = countries.query('Population2020 > 1e6 and Country >= "Si" and␣
↪Country <= "Sz"')
life_exp_iso3 = life_exp.reset_index().set_index('ISO3')
life_exp_sel = life_exp_iso3.loc[life_exp_iso3.index.intersection(selection.
↪ISO3), :].set_index('Country')
display(life_exp_sel)
```

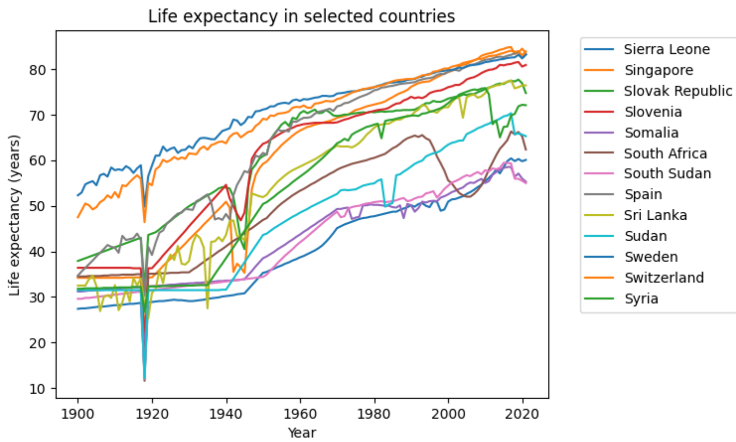
	1900	1901	1902	1903	1904	1905	1906	1907	1908	1909	\
Country											
Sierra Leone	27.4	27.5	27.5	27.6	27.7	27.8	27.9	27.9	28.0	28.1	
Singapore	34.2	34.2	34.2	34.2	34.2	34.2	34.2	34.2	34.2	34.2	
Slovak Republic	37.9	38.2	38.5	38.8	39.1	39.4	39.7	40.0	40.3	40.6	
Slovenia	36.4	36.4	36.4	36.4	36.4	36.4	36.4	36.4	36.4	36.4	
Somalia	31.2	31.2	31.3	31.4	31.4	31.5	31.5	31.6	31.7	31.7	
South Africa	34.5	34.5	34.5	34.6	34.6	34.6	34.6	34.7	34.7	34.8	
South Sudan	29.6	29.6	29.8	29.8	29.9	30.0	30.1	30.2	30.3	30.4	
Spain	34.7	35.6	36.4	37.2	38.0	38.9	39.7	40.5	41.4	41.0	
Sri Lanka	32.5	32.5	32.5	33.9	34.7	32.4	26.9	30.0	30.4	29.8	
Sudan	31.5	31.5	31.5	31.5	31.5	31.5	31.5	31.5	31.5	31.5	
Sweden	52.3	52.9	54.7	55.1	55.4	54.5	56.7	57.0	56.4	58.4	
Switzerland	47.5	49.0	50.5	50.1	49.2	49.7	50.8	51.3	52.3	51.7	
Syria	31.8	31.8	31.9	31.9	31.9	31.9	31.9	32.0	32.0	32.0	

```
                  …  2012  2013  2014  2015  2016  2017       2018  \
Country           …
Sierra Leone      …  56.9  57.9  57.1  58.5  59.8  60.4  59.796000
Singapore         …  83.6  83.9  84.2  84.4  84.7  84.8  83.297561
Slovak Republic   …  76.2  76.6  76.8  76.7  77.2  77.4  77.265854
Slovenia          …  79.9  80.2  80.9  80.8  81.0  81.1  81.378049
Somalia           …  56.8  57.4  57.9  58.3  58.5  58.5  56.375000
South Africa      …  59.5  61.1  62.5  63.4  64.4  66.3  65.674000
South Sudan       …  58.2  58.0  58.3  59.4  59.4  59.3  55.950000
Spain             …  82.3  82.6  82.7  82.6  82.9  83.1  83.431707
Sri Lanka         …  76.1  76.4  76.5  76.9  77.2  77.5  75.748000
Sudan             …  68.4  68.7  69.1  69.6  69.8  70.3  65.681000
Sweden            …  81.8  81.9  82.1  82.2  82.4  82.5  82.558537
Switzerland       …  82.9  83.0  83.3  83.5  83.8  84.0  83.753659
Syria             …  67.9  68.7  65.0  67.3  67.4  69.8  70.145000

                      2019       2020       2021
Country
Sierra Leone     60.255000  59.763000  60.062000
Singapore        83.595122  84.465854  83.441463
Slovak Republic  77.665854  76.865854  74.714634
Slovenia         81.529268  80.531707  80.875610
Somalia          57.078000  55.967000  55.280000
South Africa     66.175000  65.252000  62.341000
South Sudan      55.912000  55.480000  54.975000
Spain            83.831707  82.331707  83.178049
Sri Lanka        76.008000  76.393000  76.399000
Sudan            65.876000  65.614000  65.267000
Sweden           83.109756  82.356098  83.156098
Switzerland      83.904878  83.000000  83.851220
Syria            71.822000  72.140000  72.063000

[13 rows x 122 columns]
```

- In Matplotlib, each country from `life_exp_sel` is plotted separately in a for-loop, similarly as for two countries above.
- Note that colors repeat because the default palette is not large enough.

[16]:
```
figure, axes = plt.subplots()
# loop over countries
for country in life_exp_sel.index:
    axes.plot(years, life_exp_sel.loc[country], label=country)

# plot settings
axes.set_xlabel('Year')
axes.set_ylabel('Life expectancy (years)')
axes.set_title('Life expectancy in selected countries')
```

```
axes.legend(bbox_to_anchor=(1.05, 1), loc=2)
pass
```



- To use Seaborn for the same plot, it is better to change `life_exp_sel` table from wide to long format using `melt` method. Year is converted from strings to integers.
- This creates a table with columns Country, Year, Expectancy.

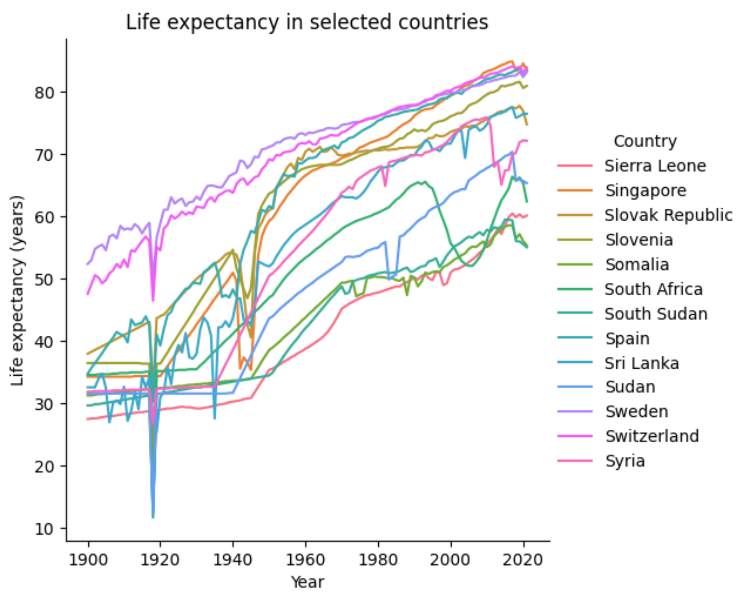
[17]:
```
life_exp_sel_long = (
    life_exp_sel.reset_index()
    .melt(id_vars=['Country'])
    .rename(columns={'variable':'Year', 'value':'Expectancy'})
    .astype({'Year':'int32'})
  )
display(life_exp_sel_long)
```

```
              Country  Year  Expectancy
0        Sierra Leone  1900   27.400000
1           Singapore  1900   34.200000
2     Slovak Republic  1900   37.900000
3            Slovenia  1900   36.400000
4             Somalia  1900   31.200000
…                   …     …           …
1581        Sri Lanka  2021   76.399000
1582            Sudan  2021   65.267000
1583           Sweden  2021   83.156098
1584      Switzerland  2021   83.851220
1585            Syria  2021   72.063000

[1586 rows x 3 columns]
```

- Now we use Seaborn function `relplot`, setting parameters `x`, `y` and `hue` to column names in our long table and specifying that we want lineplit using `kind="line"`.

- The function returns FacetGrid, which potentially contains multiple axes, so we ned to use slightly different methods to set labels.
- Seaborn created a sufficiently large color palette but some colors are then hard to distinguish.

[18]:
```
grid = sns.relplot(data=life_exp_sel_long, x='Year', y='Expectancy',
                   hue='Country', kind="line")
grid.set_axis_labels('Year', 'Life expectancy (years)')
grid.set(title='Life expectancy in selected countries')
pass
```



1.17 Small multiples

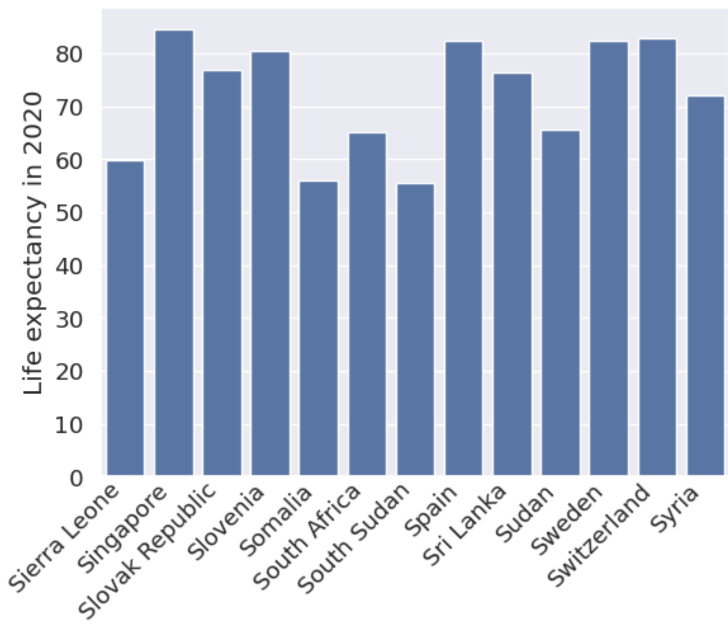
- Small multiples, with each country in our selection as a separate plot, is very easy to do in Seaborn from a long-format table using relplot, using column Country in option col which selects one of subplots for each data point.
- Option col_wrap selects how many subplots will be placed ion one row of the overall figure.

[19]:
```
# create grid of small multiple plots
sns.set_theme(font_scale=1.2)
grid = sns.relplot(data=life_exp_sel_long,
                   x='Year', y='Expectancy', col='Country',
                   col_wrap=5, kind="line", height=3, aspect=1)

grid.set_axis_labels('Year', 'Life expectancy (years)')
grid.set_titles("{col_name}")  # title of each plot will be country name
pass
```

1.18 Bar graph

- We plot a bargraph of life expectancy in our selected countries by Seaborn function `barplot`.
- All bars are plotted by the same color using setting `color="C0"`.
- We rotate tick labels on the x axes to fit them in the given space.

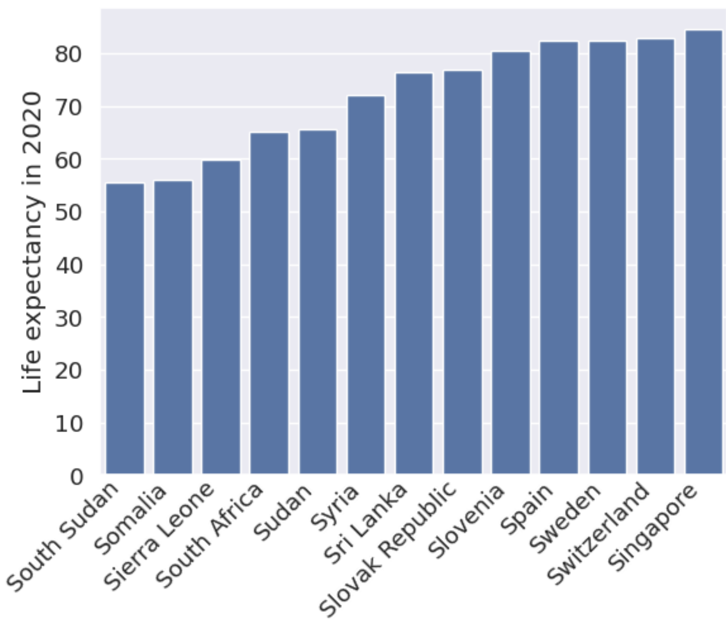
[20]:
```
def rotate_bar_labels(axes, angle=45):
    """Auxiliary function for rotating bar plot labels by 45 degrees"""
    axes.tick_params(axis='x', labelrotation=angle, pad=-5)
    plt.setp(axes.get_xticklabels(), ha='right')


# select one year from the long table
life_exp_sel_2020 = life_exp_sel_long.query('Year==2020')
# create barplot
axes = sns.barplot(data=life_exp_sel_2020,
                   x='Country', y='Expectancy', color="C0")
axes.set_ylabel("Life expectancy in 2020")
axes.set_xlabel(None)
rotate_bar_labels(axes)
pass
```



1.19 Bar graph with sorted columns

Countries are sorted by value in preprocessing, then plotted as before.

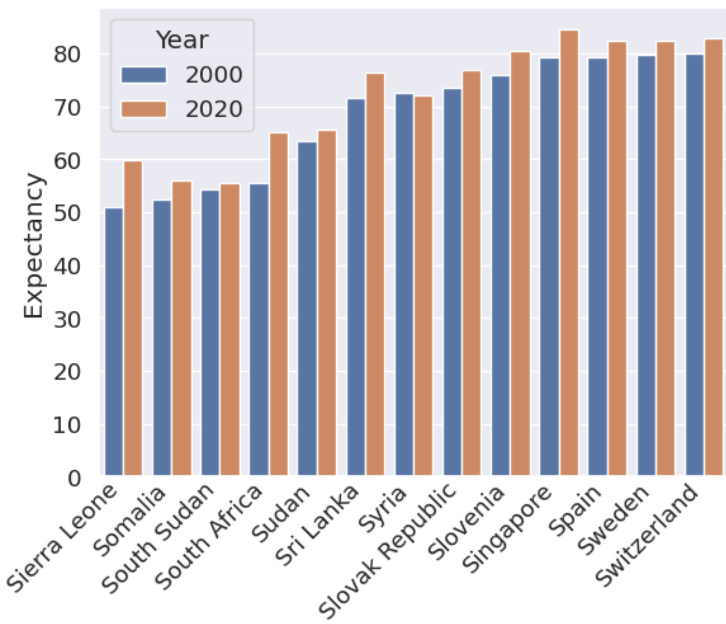
[21]:
```
# sorting
life_exp_sel_2020_sorted = life_exp_sel_2020.sort_values('Expectancy')
# plotting
axes = sns.barplot(data=life_exp_sel_2020_sorted,
                   x='Country', y='Expectancy', color="C0")
axes.set_ylabel("Life expectancy in 2020")
axes.set_xlabel(None)
rotate_bar_labels(axes)
pass
```



1.20 Bar graph with multiple colors

- Now we compare life expectancy in two years in a bargraph with tho colors of columns.
- After selecting appropriate rows of the long table, we use column `Year` in the `hue` parameter of `barplot`.

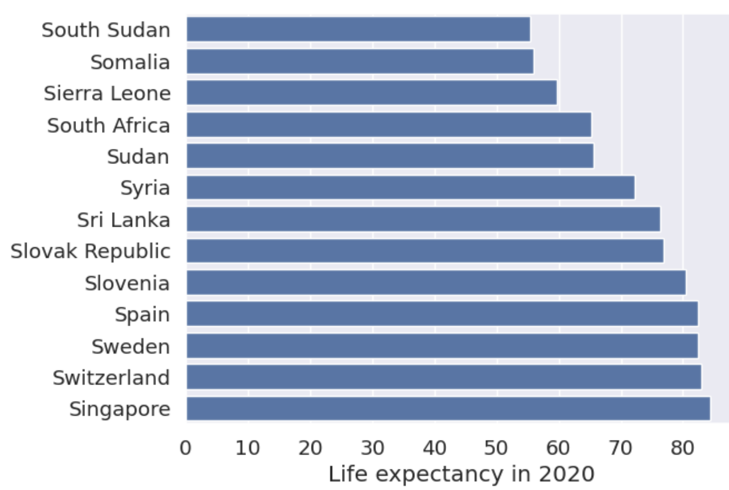
[22]:
```
# we will use only years 2000 and 2020 from the table
# we convert the list of years to categorical type for better display
selected_years = [2000, 2020]
year_cat_type = pd.api.types.CategoricalDtype(categories=selected_years,
                                              ordered=True)

# we select only two years, sort the table
# and convert Year column to categorical type
life_exp_sel_comp = (life_exp_sel_long.query('Year in @selected_years')
                     .sort_values('Expectancy')
                     .astype({'Year': year_cat_type}))

# plotting
axes = sns.barplot(data=life_exp_sel_comp, x='Country', y='Expectancy',␣
 ↪hue='Year')
axes.set_xlabel(None)
rotate_bar_labels(axes)
pass
```



1.21 Horizontal bar graph

- Longer bar labels are easier to read in a horizontal barplot.
- In Seaborn, it is sufficent to switch `x` and `y` arguments.

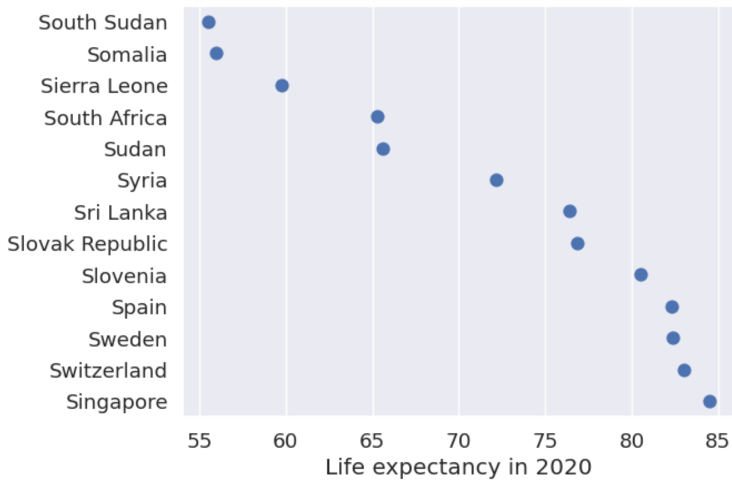
[23]:
```
axes = sns.barplot(data=life_exp_sel_2020_sorted,
                   y='Country', x='Expectancy', color="C0")
axes.set_xlabel("Life expectancy in 2020")
axes.set_ylabel(None)
pass
```



1.22 Dot plot

- Dot plot shows only the end of each bar as a dot.
- Seaborn's pointplot joins these dots by lines by default, `linestyle='none'` prevents this.
- Note that in contrast to barplots, the x axis does not start at 0 (we could make it so by `set_xlim`).

[24]:
```
axes = sns.pointplot(data=life_exp_sel_2020_sorted,
                     y='Country', x='Expectancy',
                     color="C0", linestyle='none')
axes.set_xlabel("Life expectancy in 2020")
axes.set_ylabel(None)
pass
```



1.23 Heatmap

- The goal is to create heatmap with countries as rows, several years as columns and life expectancy values as colors.
- We first need to create a DataFrame with these values in such an arrangment by selecting rows with appropriate years from our long table and pivoting the table by year to make it wide.
- Finally we sort the table by the expectancy in the last year.

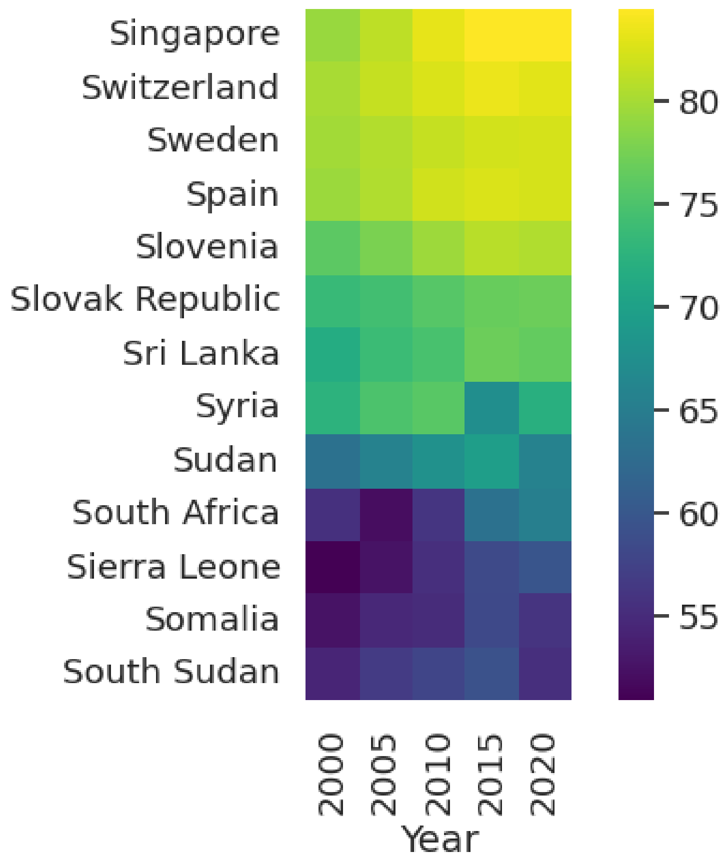
[25]:
```
# set of years to be used
sel_years={2000, 2005, 2010, 2015, 2020}
# create desired wide table
life_exp_sel_wide = (life_exp_sel_long.query('Year in @sel_years')
                     .pivot(index='Country', columns='Year',␣
 ↪values='Expectancy')
                     .sort_values(2020, ascending=False))
# show the table
```

```
display(life_exp_sel_wide)
```

```
Year               2000  2005  2010  2015       2020
Country
Singapore          79.3  81.1  83.2  84.4  84.465854
Switzerland        80.1  81.5  82.5  83.5  83.000000
Sweden             79.8  80.6  81.5  82.2  82.356098
Spain              79.4  80.5  82.0  82.6  82.331707
Slovenia           76.0  77.7  79.5  80.8  80.531707
Slovak Republic    73.5  74.3  75.6  76.7  76.865854
Sri Lanka          71.6  73.8  74.7  76.9  76.393000
Syria              72.5  75.0  75.8  67.3  72.140000
Sudan              63.4  65.7  67.7  69.6  65.614000
South Africa       55.6  52.0  56.1  63.4  65.252000
Sierra Leone       50.9  52.6  55.4  58.5  59.763000
Somalia            52.5  54.7  55.0  58.3  55.967000
South Sudan        54.4  56.7  57.8  59.4  55.480000
```

- Heatmap is plotted by `sns.heatmap` function.
- We have used options to set the shape of individual cells to square and change the color palette (`cmap`).

[26]:
```
axes = sns.heatmap(data=life_exp_sel_wide, square=True, cmap="viridis")
axes.set_ylabel(None)
pass
```



1.24 Pie chart

- To prepare data for pie chart, we use two features of Pandas which we will cover in a later lecture: converting the Income Group column to a categorical type and computing the number of countries in various income groups using `groupby`.
- In this way we create two Series: `groups` with counts for the whole world and `groups_asia` for just East Asian countries.

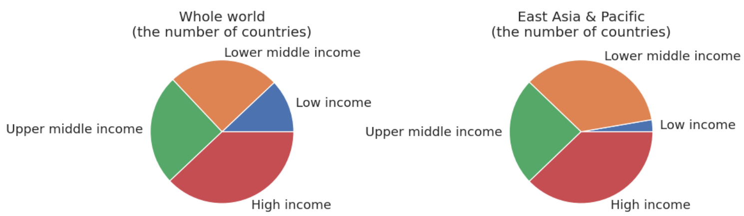
[27]:
```
# creating a categorical type
income_categories = ["Low income", "Lower middle income",
                     "Upper middle income", "High income"]
cat_type = pd.api.types.CategoricalDtype(categories=income_categories,
                                         ordered=True)
# converting Income Group column to cat_type
countries_cat = countries.astype({'Income Group': cat_type})
# aggregation using groupby
groups = countries_cat.groupby('Income Group', observed=False).size().
 ↪rename('Count')
# the same but only on countries selected by query
```

```
groups_asia = (countries_cat.query('Region=="East Asia & Pacific"')
               .groupby('Income Group', observed=False).size().rename('Count'))

display(groups)
```

```
Income Group
Low income             26
Lower middle income    54
Upper middle income    54
High income            82
Name: Count, dtype: int64
```

- The plotting is done by the pie function from Matplotlib.
- It gets the series with counts as parameter `x` and country names as `labels`.

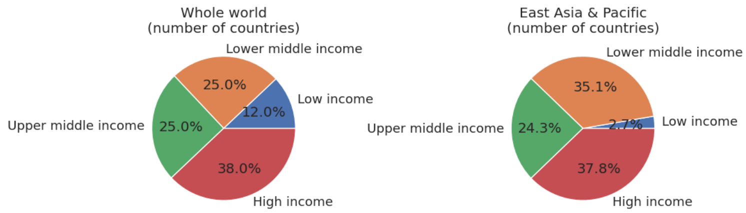
[28]:
```
figure, axes = plt.subplots(1,2, figsize=(10,5))
axes[0].pie(x=groups, labels=groups.index)
axes[0].set_title('Whole world\n(the number of countries)')
axes[1].pie(x=groups_asia, labels=groups_asia.index)
axes[1].set_title('East Asia & Pacific\n(the number of countries)')
figure.subplots_adjust(wspace=1)
pass
```



1.25 Pie chart with labels

- Labels are added by `autopct` setting in pie. This setting provides a formatting string for the values, here we print one decimal place.

[29]:
```
figure, axes = plt.subplots(1,2, figsize=(10,5))
axes[0].pie(x=groups, labels=groups.index, autopct="%.1f%%")
axes[0].set_title('Whole world\n(number of countries)')
axes[1].pie(x=groups_asia, labels=groups_asia.index, autopct="%.1f%%")
axes[1].set_title('East Asia & Pacific\n(number of countries)')
figure.subplots_adjust(wspace=1)
pass
```



1.26 Stacked bar graph instead of pie chart

- To prepare data for stacked bar graph, we need to combine our two count Series (`groups` and `groups_asia`) to one long table `groups_concat`.
- This is a DataFrame, because `Income Group` was moved from index to a column.
- We also add percentage column, which will be used in the plot. Percentage is computed by divided counts with the sum of all counts.
- We also add a column with region name, because we will consider two regions (East Asia and the whole world).

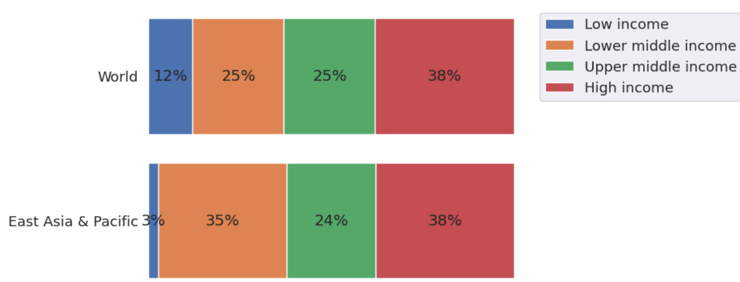
[30]:
```
# first create DataFrame for East Asia
# add Income Group index as a column
temp_asia = groups_asia.reset_index()
# compute percentages and add as a new column
temp_asia['Percentage'] = temp_asia['Count'] * 100 / temp_asia['Count'].sum()
# add Region as a new column, filled with copies of the same string
temp_asia['Region'] = ["East Asia & Pacific"] * len(groups_asia)

# the same three steps for World
temp_world = groups.reset_index()
temp_world['Percentage'] = temp_world['Count'] * 100 / temp_world['Count'].sum()
temp_world['Region'] = ["World"] * len(groups)

# concatenate two DataFrames and display
groups_concat = pd.concat([temp_asia, temp_world], axis=0)
display(groups_concat)
```

	Income Group	Count	Percentage	Region
0	Low income	1	2.702703	East Asia & Pacific
1	Lower middle income	13	35.135135	East Asia & Pacific
2	Upper middle income	9	24.324324	East Asia & Pacific
3	High income	14	37.837838	East Asia & Pacific
0	Low income	26	12.037037	World
1	Lower middle income	54	25.000000	World
2	Upper middle income	54	25.000000	World
3	High income	82	37.962963	World

- Stacked bar graph is not very automated in Matplotib.

- Left coordinate for each rectangle needs to be computed manually, then function `barh` is used (see also tutorial).
- Each bar is labeled with the percentage using `bar_label` function.

[31]:
```
# list of regions and income groups
tmp_regions = groups_concat['Region'].unique()
tmp_groups = groups_concat['Income Group'].unique()
# the first rectangles start at 0
starts = pd.Series([0] * tmp_regions.shape[0])
# create plot
figure, axes = plt.subplots()

# iterate through income groups
for group in tmp_groups:
    # select data for this income group from both regions
    tmp_data = groups_concat.query("`Income Group` == @group")
    # plot
    rectangles = axes.barh(y=tmp_data['Region'], width=tmp_data['Percentage'],␣
↪left=starts, label=group)
    # add labels
    axes.bar_label(rectangles, label_type='center', fmt="%.0f%%")
    # move starts by the size of each rectangle
    starts += tmp_data['Percentage'].reset_index(drop=True)

axes.legend(bbox_to_anchor=(1, 1), loc=2)
# hide plot frame and x-axis ticks
axes.xaxis.set_visible(False)
axes.set_frame_on(False)
pass
```



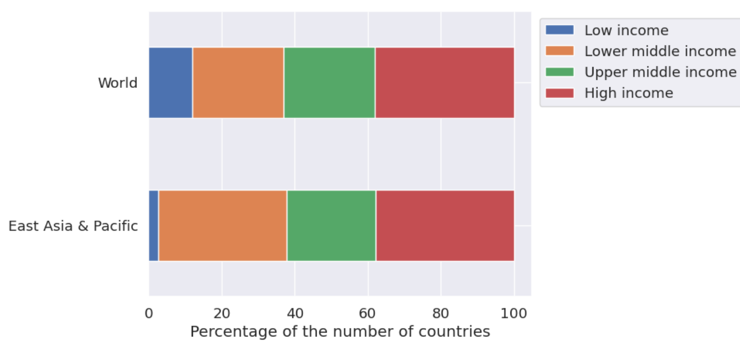
- Stacked bar charts are much easier in Plotly using `px.bar` function.

[32]:
```
fig = px.bar(groups_concat, x="Region", y="Percentage", color="Income Group",
             text="Percentage", text_auto=".0f")
fig.update_layout(font=dict(size=20), xaxis_title=None,)
fig.show()
```

It can also be drawn easily directly by Pandas, but values (sizes of rectangles) are not shown. The table is first converted toa wide form with different income groups as columns.

[33]:
```
groups_concat_wide = groups_concat.pivot(columns='Income Group',␣
↪index='Region', values='Percentage')
display(groups_concat_wide)
axes = groups_concat_wide.plot(kind='barh', stacked=True)
axes.legend(bbox_to_anchor=(1, 1), loc=2)
axes.set_ylabel(None)
axes.set_xlabel('Percentage of the number of countries')
pass
```

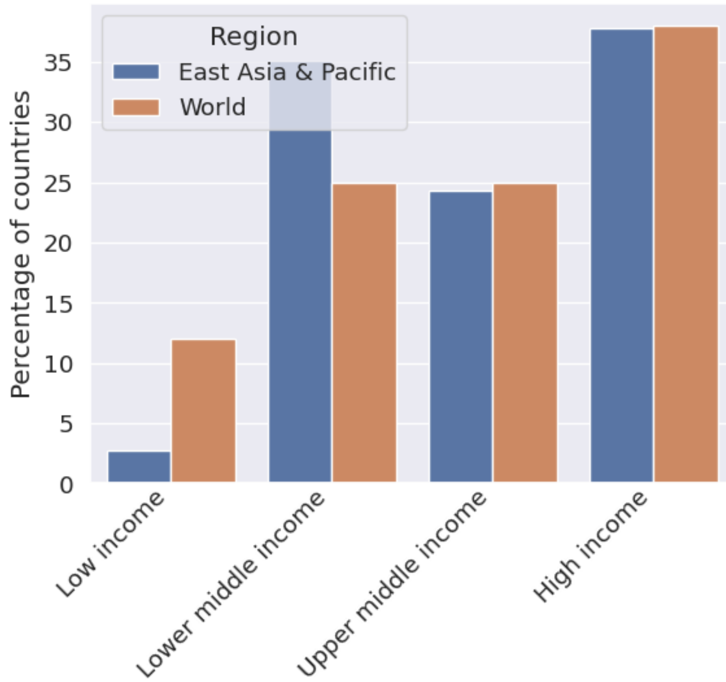
```
Income Group          Low income  Lower middle income  Upper middle income  \
Region
East Asia & Pacific     2.702703            35.135135            24.324324
World                  12.037037            25.000000            25.000000

Income Group          High income
Region
East Asia & Pacific     37.837838
World                   37.962963
```



1.27 Colored bar graphs insteads of pie chart

- As we have seen before, colored bar graphs are easy in Seaborn from a long table.
- Therefore we use `groups_concat` DataFrame.

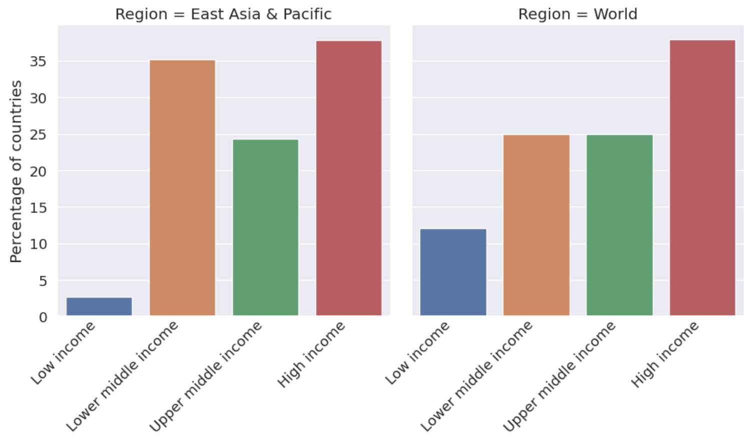
[34]:
```
axes = sns.barplot(data=groups_concat,
                   x='Income Group', y='Percentage', hue='Region')
rotate_bar_labels(axes)
axes.set_xlabel(None)
axes.set_ylabel("Percentage of countries")
pass
```



1.28 Multiple bar graphs instead of pie chart

- In the next plot a separte bar graph for each region.
- This is also very simple in Seaborn using `catplot` with setting `col='Region'` and `kind='bar'`.
- Labels are rotated in each subplot using a for-loop.

[35]:
```
grid = sns.catplot(kind='bar', data=groups_concat,
                   x='Income Group', y='Percentage',
                   col='Region', hue='Income Group')

# label rotation
for which in [0,1]:
  rotate_bar_labels(grid.axes[0,which])
  grid.axes[0,which].set_xlabel(None)
  grid.axes[0,which].set_ylabel("Percentage of countries")
pass
```



1.29 Stacked area plot

- In a stack area plot we plot several area plots above each other.
- In this example, in each year in history, we split countries into groups by life expectancy and plot the number of countries in each category.
- First we need to transform our table to an appropriate form, then we use `px.area` from Plotly which supports this plot well.

[36]:
```
# Integer division // is used trnasfor life expectancy into decades
# e.g. all values between 60 and 69 are transformed to 60
life_exp_decades = (life_exp_years // 10 * 10).astype('int32')
# Now we change to long table format with columns Country, Year and Expectancy
life_exp_decades_long = (life_exp_decades
                         .reset_index()
                         .melt(id_vars=['Country'])
                         .rename(columns={'variable':'Year', 'value':
 ↪'Expectancy'})
                         .astype({'Year':'int32'})
                         )
# Group countries by year and expectancy decade, compute size of each group
life_exp_decades_grouped = life_exp_decades_long.groupby(['Year',␣
 ↪'Expectancy']).size().reset_index(name='Countries')
# Get all values of expectancy decade, sort them numerically
decades_values = life_exp_decades_long["Expectancy"].unique()
decades_values.sort()

display("Long table with decades:", life_exp_decades_long.head())
display("Country counts per year and expectancy decades",␣
 ↪life_exp_decades_grouped)
display("Values of decades:", decades_values)
```

```
'Long table with decades:'
```

```
                Country  Year  Expectancy
0           Afghanistan  1900          20
1               Albania  1900          30
2               Algeria  1900          30
3                Angola  1900          20
4   Antigua and Barbuda  1900          30
```

```
'Country counts per year and expectancy decades'
```

```
     Year  Expectancy  Countries
0    1900          10          1
1    1900          20         43
2    1900          30        111
3    1900          40         25
4    1900          50          4
..    …           …          …
601  2020          80         28
602  2021          50         17
603  2021          60         53
604  2021          70         86
605  2021          80         28

[606 rows x 3 columns]
```

```
'Values of decades:'
```

```
array([ 0, 10, 20, 30, 40, 50, 60, 70, 80], dtype=int32)
```

[37]:

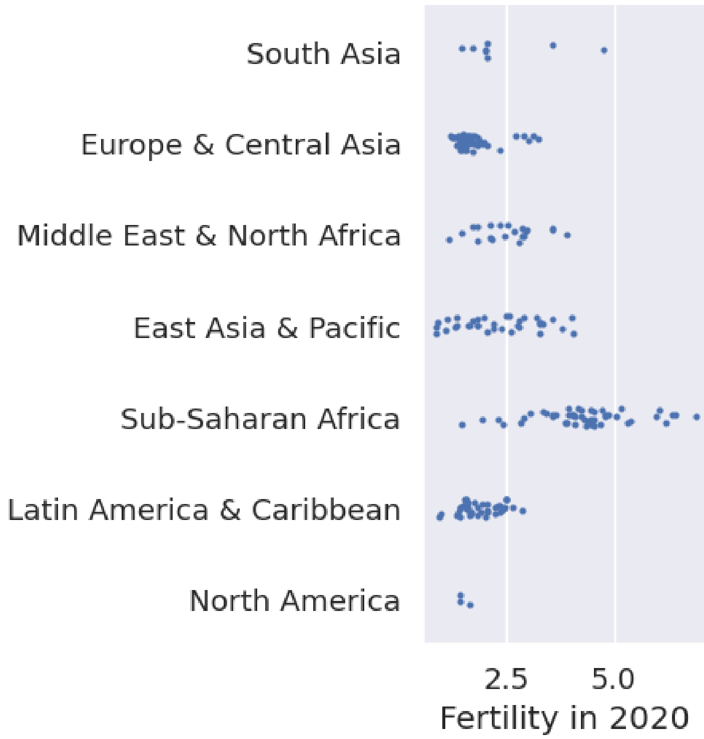
```
fig = px.area(life_exp_decades_grouped, x="Year", y="Countries",
              color="Expectancy",
              category_orders={"Expectancy":decades_values},   # this orders␣
 ↪areas by value
              color_discrete_sequence=px.colors.sequential.Plasma_r  # this␣
 ↪sets color palette
              )
fig.show()
```

1.30 Strip plot

- Strip plot of fertility per region is also very simple in `sns.catplot`.
- Setting `kind='strip'` is default for `catplot`, so it is omitted here.
- Size of dots is reduced to limit overlapping markers.

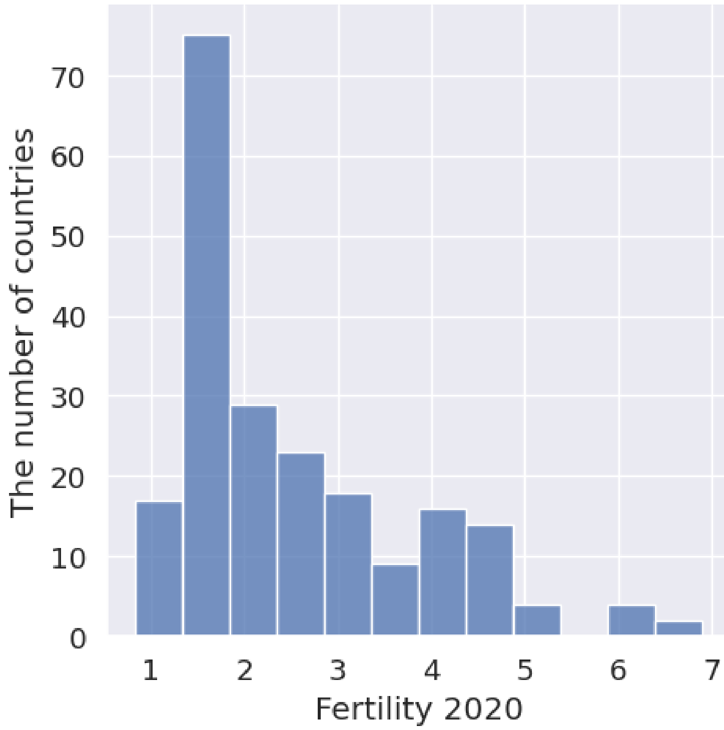
[38]:

```
grid = sns.catplot(x="Fertility2020", y="Region", data=countries, size=3)
grid.set_axis_labels("Fertility in 2020", "")
pass
```



1.31 Histogram

[39]:
```
grid = sns.displot(countries, x="Fertility2020", binwidth=0.5)
grid.set_axis_labels("Fertility 2020", "The number of countries")
pass
```



1.32 Parallel coordinates

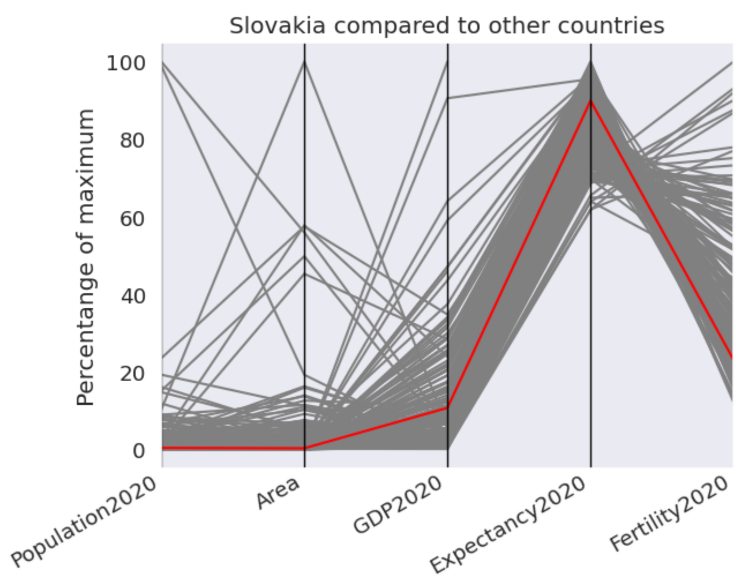
- We want to display varipus properties of individual countries as parallel coordinate plot.
- We first create table `for_parallel` with selected columns and express all numbers as percentage of the maximum value.
- We add `selected` column which has True in row for Slovakia and False elsewhere. This is used to highlight Slovakia in the plot.
- Also ordering is changed to draw Slovakia the last.

[40]:
```
# selecting columns
for_parallel_sel = countries.loc[:, ['Population2020', 'Area', 'GDP2020',
                                     'Expectancy2020', 'Fertility2020']]
# computing maximum in each column
for_parallel_max = for_parallel_sel.max(axis=0)
# dividing values by the maximum and multiplying by 100 to get percentage
for_parallel = for_parallel_sel.div(for_parallel_max, axis=1) * 100
# creating column of booleans called 'selected' which highlights Slovakia with␣
↪True
for_parallel['selected'] = countries.index=="Slovak Republic"
# sort by 'selected' to put Slovakia last
for_parallel.sort_values('selected', inplace=True)
# show end of the table
display(for_parallel.tail())
```

```
                 Population2020      Area    GDP2020  Expectancy2020  \
Country
Greece                 0.758174  0.771775   9.651333       95.076168
Greenland              0.003995  2.400538  29.962671       83.788155
Fiji                   0.065227  0.106853   2.638193       79.445541
Zimbabwe               1.110458  2.285380   0.752009       71.492098
Slovak Republic        0.386849  0.286754  10.711280       89.904148

                 Fertility2020  selected
Country
Greece               20.168311     False
Greenland            29.294835     False
Fiji                 36.201393     False
Zimbabwe             51.436448     False
Slovak Republic      23.070226      True
```

- Parallel coordinates are drawn using Pandas `parallel_coordinates` function, which internally calls Matplotlib and returns Axes object.

[41]:
```
axes = pd.plotting.parallel_coordinates(for_parallel, class_column='selected',
                                        color=['gray', 'red'])
axes.get_legend().remove()
axes.set_ylabel("Percentange of maximum")
axes.set_title("Slovakia compared to other countries")
rotate_bar_labels(axes, angle=30)
pass
```



1.33 Parallel categories

- We will use two categorical columns from the countries table, but more categorical columns could be easily added.
- We use the version of the table with a categorical income groups and sort countries by income.
- Now we use `parallel_categories` function from Plotly.
- This function orders each column of the figure by size. By calling `update_traces`, we reorder the first column by the same order as they first occur in our table.

[42]:
```
for_parallel_cat = (countries_cat.loc[:,['Income Group','Region']]
                    .sort_values('Income Group', ascending=False))
fig = px.parallel_categories(for_parallel_cat, width=800)
fig.update_traces(dimensions=[{"categoryorder": "array"}, {}])
fig.update_layout(font_size=20)
fig.update_layout(margin={'l':200,'r':200})
fig.show()
```

1.34 Radar chart

- Radar charts are not well supported in any of the used libraries.
- Below we compute angles of each axis manually, then use `plot` from Matplotlib.
- When creating axes, we specify polar coordinates `subplot_kw={'projection': 'polar'}`.
- We also use `set_thetagrids` to show a line for each axis.

[43]:
```
# skip 'selected' column, use only 3 countries
for_radar = for_parallel.loc[['India','China','United States'], :].iloc[:, 0:-1]
display(for_radar.head())

# setup plot with polar coordinates
sns.set_theme(style="whitegrid")
figure, axes = plt.subplots(subplot_kw={'projection': 'polar'})
categories = list(for_radar.columns)
import math
angles = [ i * 2 * math.pi / len(categories) for i in range(len(categories))]
angles_deg = [x / math.pi * 180 for x in angles]
axes.set_thetagrids(angles_deg, labels=categories)

# for plotting, we will need to return to the starting point in each line
angles.append(angles[0])

# for each country create list of values, add the starting point, plot
for country in for_radar.index:
    values = list(for_radar.loc[country, :])
    values.append(values[0])
    axes.plot(angles, values, label=country)
    axes.fill(angles, values, alpha=0.25)

axes.legend(bbox_to_anchor=(1.05, 1), loc=2)
```

```
pass
```

```
               Population2020       Area    GDP2020  Expectancy2020  \
Country
India               98.957347  19.225710   1.048125       82.049124
China              100.000000  55.929174   5.702240       91.320734
United States       23.493127  57.500095  34.803081       90.038227

               Fertility2020
Country
India              29.759141
China              18.586767
United States      23.817470
```