Introduction to Python

Tom Paskhalis

RECSM Summer School 2021, Exploratory Data Analysis & Data Visualization, Part 4, Day 2

Exploratory data analysis

- "Exploratory data analysis can never be the whole story, but nothing else can serve as the foundation stone--as the first step." (Tukey, 1977)
- Exploratory data analysis (EDA) is the first and often most important step in research
- Study's feasibility, scope and framing would usually depend on its results
- Specific details of EDA depend upon the type and quality of data available

Measurement scales

TABLE 1

Scale	Basic Empirical Operations	Mathematical Group Structure	Permissible Statistics (invariantive)
NOMINAL	Determination of equality	*Permutation group* $x' = f(x)$ $f(x)$ means any one-to-one substitution	Number of cases Mode Contingency correlation
ORDINAL	Determination of greater or less	*Isotonic group* $x' = f(x)$ $f(x)$ means any monotonic increasing function	Median Percentiles
INTERVAL	Determination of equality of intervals or differences	*General linear group* $x' = ax + b$	Mean Standard deviation Rank-order correlation Product-moment correlation
RATIO	Determination of equality of ratios	*Similarity group* $x' = ax$	Coefficient of variation

Source: Stevens (1946)

Measurement scales in Pandas

- The 4 measurement scales defined by Stevens (1946) can be roughly represented in pandas as follows:
- *Interval* and *ratio* -> numeric
- *Nominal* and *ordinal* -> categorical

Loading the dataset

Loading the dataset

In [1]:
```
import pandas as pd
```

Loading the dataset

In [1]:
```
import pandas as pd
```

In [2]:
```
# This time let's skip the 2nd row, which contains questions
kaggle2020 = pd.read_csv('../data/kaggle_survey_2020_responses.csv', skiprows = [1]
kaggle2020.head(n = 1)
```

Out[2]:

	Time from Start to Finish (seconds)	Q1	Q2	Q3	Q4	Q5	Q6	Q7_Part_1	Q7_Part_2	Q7_Part_3	...	Q35_B_Part_2
0	1838	35-39	Man	Colombia	Doctoral degree	Student	5-10 years	Python	R	SQL	...	NaN

1 rows × 355 columns

Loading the dataset

In [1]:
```
import pandas as pd
```

In [2]:
```
# This time let's skip the 2nd row, which contains questions
kaggle2020 = pd.read_csv('../data/kaggle_survey_2020_responses.csv', skiprows = [1]
kaggle2020.head(n = 1)
```

Out[2]:

	Time from Start to Finish (seconds)	Q1	Q2	Q3	Q4	Q5	Q6	Q7_Part_1	Q7_Part_2	Q7_Part_3	...	Q35_B_Part_2
0	1838	35-39	Man	Colombia	Doctoral degree	Student	5-10 years	Python	R	SQL	...	NaN

1 rows × 355 columns

In [3]:
```
# We will load the questions as a separate dataset
kaggle2020_qs = pd.read_csv('../data/kaggle_survey_2020_responses.csv', nrows = 1)
kaggle2020_qs
```

Summarizing numeric variables

- DataFrame methods in pandas can automatically handle (exclude) missing data (`NaN`)

Summarizing numeric variables

- DataFrame methods in pandas can automatically handle (exclude) missing data (`NaN`)

In [4]:
```
kaggle2020.describe() # DataFrame.describe() provides an range of summary statistic
```

Out[4]:

	Time from Start to Finish (seconds)
count	2.003600e+04
mean	9.155865e+03
std	6.136760e+04
min	2.000000e+01
25%	3.980000e+02
50%	6.260000e+02
75%	1.030250e+03
max	1.144493e+06

Methods for summarizing numeric variables

Methods for summarizing numeric variables

In [5]:
```
kaggle2020.iloc[:,0].mean() # Rather than using describe(), we can apply individual
```

Out[5]:
```
9155.864843282092
```

Methods for summarizing numeric variables

In [5]:
```
kaggle2020.iloc[:,0].mean() # Rather than using describe(), we can apply individual
```

Out[5]: 9155.864843282092

In [6]:
```
kaggle2020.iloc[:,0].median() # Median
```

Out[6]: 626.0

Methods for summarizing numeric variables

In [5]:
```
kaggle2020.iloc[:,0].mean() # Rather than using describe(), we can apply individual
```

Out[5]: 9155.864843282092

In [6]:
```
kaggle2020.iloc[:,0].median() # Median
```

Out[6]: 626.0

In [7]:
```
kaggle2020.iloc[:,0].std() # Standard deviation
```

Out[7]: 61367.59967471586

Methods for summarizing numeric variables

In [5]:
```
kaggle2020.iloc[:,0].mean() # Rather than using describe(), we can apply individual
```

Out[5]: 9155.864843282092

In [6]:
```
kaggle2020.iloc[:,0].median() # Median
```

Out[6]: 626.0

In [7]:
```
kaggle2020.iloc[:,0].std() # Standard deviation
```

Out[7]: 61367.59967471586

In [8]:
```
import statistics ## We don't have to rely only on methods provided by `pandas`
statistics.stdev(kaggle2020.iloc[:,0])
```

Out[8]: 61367.59967471586

Summarizing categorical variables

Summarizing categorical variables

In [9]:
```
kaggle2020.describe(include = 'all') # Adding include = 'all' tells pandas to summa
```

Out[9]:

	Time from Start to Finish (seconds)	Q1	Q2	Q3	Q4	Q5	Q6	Q7_Part_1	Q7_Part_2	Q7_Part_3	...	Q
count	2.003600e+04	20036	20036	20036	19569	19277	19120	15530	4277	7535	...	1
unique	NaN	11	5	55	7	13	7	1	1	1	...	1
top	NaN	25-29	Man	India	Master's degree	Student	3-5 years	Python	R	SQL	...	W B
freq	NaN	4011	15789	5851	7859	5171	4546	15530	4277	7535	...	1
mean	9.155865e+03	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	...	N
std	6.136760e+04	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	...	N
min	2.000000e+01	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	...	N
25%	3.980000e+02	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	...	N
50%	6.260000e+02	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	...	N
75%	1.030250e+03	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	...	N
max	1.144493e+06	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	...	N

11 rows × 355 columns

Methods for summarizing categorical variables

Methods for summarizing categorical variables

In [10]:
```
kaggle2020.iloc[:,2].mode() # Mode, most frequent value
```

Out[10]:
```
0    Man
dtype: object
```

Methods for summarizing categorical variables

In [10]:
```
kaggle2020.iloc[:,2].mode() # Mode, most frequent value
```

Out[10]:
```
0    Man
dtype: object
```

In [11]:
```
kaggle2020.iloc[:,2].value_counts() # Counts of unique values
```

Out[11]:
```
Man                          15789
Woman                         3878
Prefer not to say              263
Prefer to self-describe         54
Nonbinary                       52
Name: Q2, dtype: int64
```

Methods for summarizing categorical variables

In [10]:
```
kaggle2020.iloc[:,2].mode() # Mode, most frequent value
```

Out[10]:
```
0    Man
dtype: object
```

In [11]:
```
kaggle2020.iloc[:,2].value_counts() # Counts of unique values
```

Out[11]:
```
Man                          15789
Woman                         3878
Prefer not to say              263
Prefer to self-describe         54
Nonbinary                       52
Name: Q2, dtype: int64
```

In [12]:
```
kaggle2020.iloc[:,2].value_counts(normalize = True) # We can further normalize them
```

Out[12]:
```
Man                          0.788032
Woman                        0.193552
Prefer not to say            0.013126
Prefer to self-describe      0.002695
Nonbinary                    0.002595
```

Summary of descriptive statistics methods

Method	Numeric	Categorical	Description
`count`	yes	yes	Number of non-NA observations
`value_counts`	yes	yes	Number of unique observations by value
`describe`	yes	yes	Set of summary statistics for Series/DataFrame
`min`, `max`	yes	yes (caution)	Minimum and maximum values
`quantile`	yes	no	Sample quantile ranging from 0 to 1
`sum`	yes	yes (caution)	Sum of values
`prod`	yes	no	Product of values
`mean`	yes	no	Mean
`median`	yes	no	Median (50% quantile)

Crosstabulation

- When working with survey data it is often useful to perform simple crosstabulations
- Crosstabulation (or *crosstab* for short) is a computation of group frequencies
- It is usually used for working with categorical variables that have a limited number of categories
- In pandas `pd.crosstab()` method is a special case of `pd.pivot_table()`

Crosstabulation in pandas

Crosstabulation in pandas

In [13]:
```
# Calculate crosstabulation between 'Age group' (Q1) and 'Gender' (Q2)
pd.crosstab(kaggle2020['Q1'], kaggle2020['Q2'])
```

Out[13]:

Q2	Man	Nonbinary	Prefer not to say	Prefer to self-describe	Woman
Q1					
18-21	2611	8	42	12	796
22-24	2838	12	41	9	886
25-29	3128	13	42	9	819
30-34	2246	8	44	9	504
35-39	1581	7	33	2	368
40-44	1153	2	15	5	222
45-49	840	1	17	4	126
50-54	605	0	10	2	81
55-59	353	0	13	0	45
60-69	362	1	4	2	29
70+	72	0	2	0	2

Margins in crosstab

Margins in crosstab

In [14]:
```
# It is often useful to see the proportions/percentages rather than raw counts
pd.crosstab(kaggle2020['Q1'], kaggle2020['Q2'], normalize = 'columns')
```

Out[14]:

Q2	Man	Nonbinary	Prefer not to say	Prefer to self-describe	Woman
Q1					
18-21	0.165368	0.153846	0.159696	0.222222	0.205260
22-24	0.179745	0.230769	0.155894	0.166667	0.228468
25-29	0.198113	0.250000	0.159696	0.166667	0.211191
30-34	0.142251	0.153846	0.167300	0.166667	0.129964
35-39	0.100133	0.134615	0.125475	0.037037	0.094894
40-44	0.073026	0.038462	0.057034	0.092593	0.057246
45-49	0.053202	0.019231	0.064639	0.074074	0.032491
50-54	0.038318	0.000000	0.038023	0.037037	0.020887
55-59	0.022357	0.000000	0.049430	0.000000	0.011604
60-69	0.022927	0.019231	0.015209	0.037037	0.007478
70+	0.004560	0.000000	0.007605	0.000000	0.000516

Crosstabulation in pandas with `pivot_table`

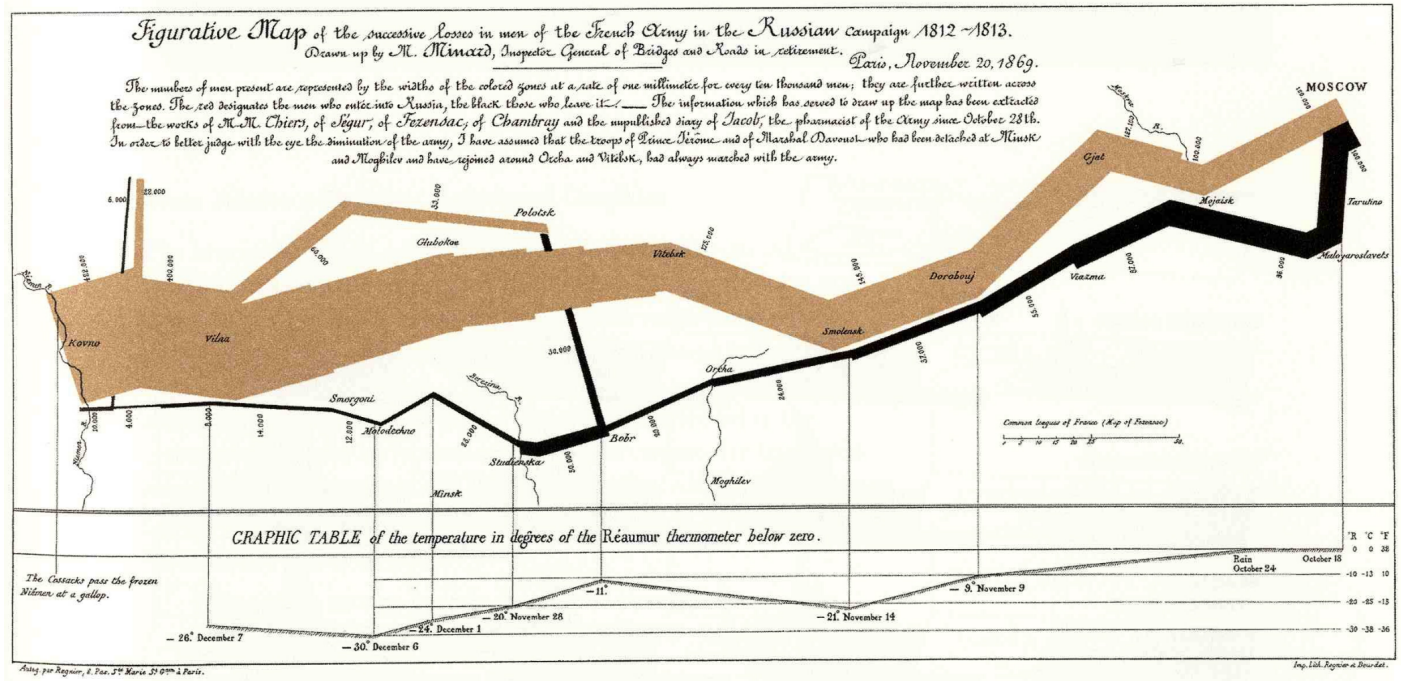
Crosstabulation in pandas with `pivot_table`

In [15]:
```
# For `values` variable we use `Q3`, but any other would work equally well
pd.pivot_table(kaggle2020, index = 'Q1', columns = 'Q2', values = 'Q3', aggfunc = '
```

Out[15]:

Q2	Man	Nonbinary	Prefer not to say	Prefer to self-describe	Woman
Q1					
18-21	2611	8	42	12	796
22-24	2838	12	41	9	886
25-29	3128	13	42	9	819
30-34	2246	8	44	9	504
35-39	1581	7	33	2	368
40-44	1153	2	15	5	222
45-49	840	1	17	4	126
50-54	605	0	10	2	81
55-59	353	0	13	0	45
60-69	362	1	4	2	29
70+	72	0	2	0	2

Data visualization



Source: Tufte (2001), based on Marey (1885)

Data visualization in Python

- As with dealing with data, Python has no in-built, 'base' plotting functionality
- `matplotlib` has become the one of standard solutions
- It is often used in combination with `pandas`
- Other popular alternative include `seaborn` and `plotnine`
- Also `pandas` itself has some limited plotting facilities

`plotnine` - `ggplot` for Python

- `plotnine` implements Grammar of Graphics data visualisation scheme (Wilkinson, 2005)
- It mimics the syntax of a well-known R library `ggplot2` syntax (Wickham, 2010)
- In doing so, it makes the code (almost) seamlessly portable between the two languages

Grammar of graphics

- Grammar of Graphics is a powerful conceptualization of plotting
- Graphs are broken into multiple layers
- Layers can be recycled across multiple plots

Structure of ggplot calls in `plotnine`

- Creation of ggplot objects in `plotline` has the following structure:

```
ggplot(data = <DATA>) +\
    <GEOM_FUNCTION>(mapping = aes(<MAPPINGS>))
```

- If the *mappings* are re-used across geometric objects (e.g. scatterplot and line):

```
ggplot(data = <DATA>, mapping = aes(<MAPPINGS>)) +\
    <GEOM_FUNCTION>() +\
```

Creating a ggplot in `plotnine`

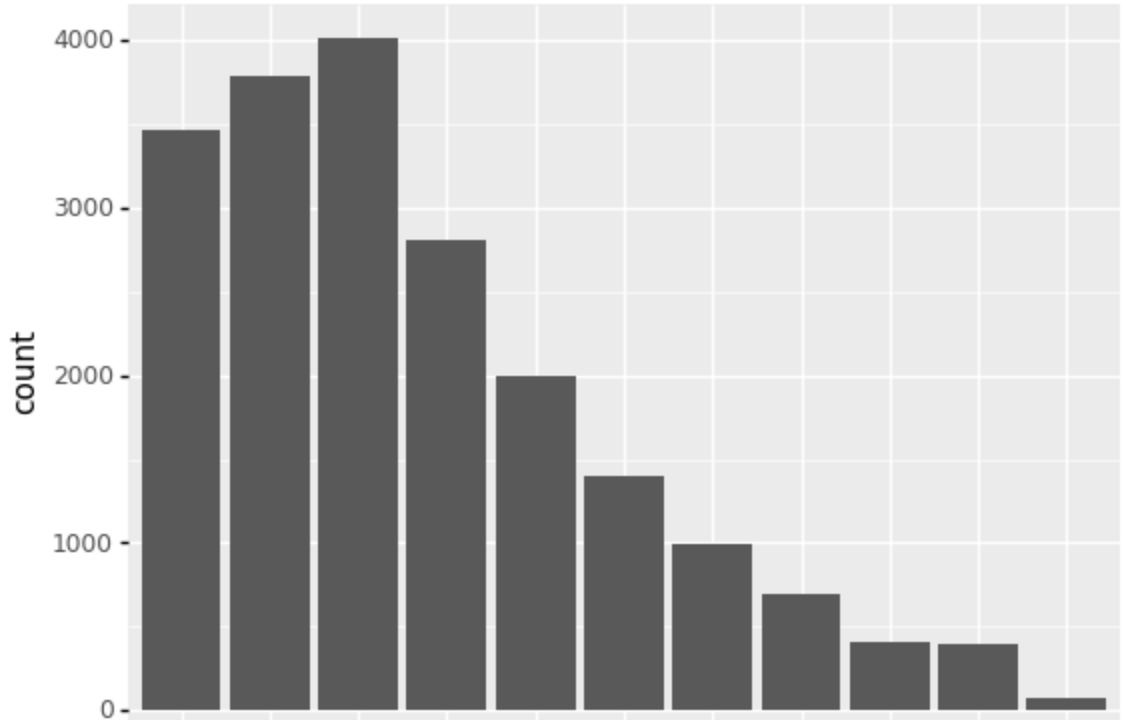
Creating a ggplot in `plotnine`

In [16]:
```
from plotnine import *
```

Creating a ggplot in `plotnine`

In [16]:
```
from plotnine import *
```

In [17]:
```
q1_plot = ggplot(data = kaggle2020) + geom_bar(aes(x = 'Q1')) # Basic 'Age group' (
q1_plot
```



Compare to base `pandas`

In [18]:
```
# First we need to group dataset by 'Age group' (Q1) and summarize it with `size()`
kaggle2020_q1_grouped = kaggle2020.groupby(['Q1']).size()
kaggle2020_q1_grouped.head(n = 3)
```

Out[18]:
```
Q1
18-21    3469
22-24    3786
25-29    4011
dtype: int64
```

Compare to base `pandas`

In [18]:
```
# First we need to group dataset by 'Age group' (Q1) and summarize it with `size()`
kaggle2020_q1_grouped = kaggle2020.groupby(['Q1']).size()
kaggle2020_q1_grouped.head(n = 3)
```

Out[18]:
```
Q1
18-21    3469
22-24    3786
25-29    4011
dtype: int64
```

In [19]:
```
kaggle2020_q1_grouped.plot(kind = 'bar')
```

Out[19]:
```
<AxesSubplot:xlabel='Q1'>
```

Compare to `matplotlib`

Compare to `matplotlib`

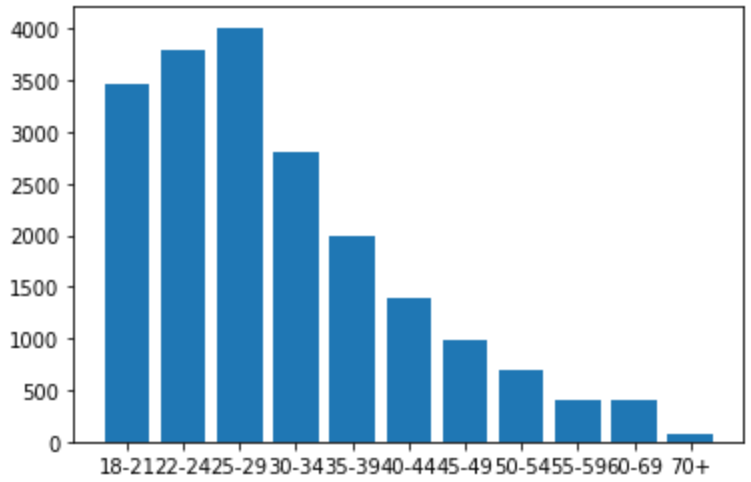
In [20]:
```
import matplotlib.pyplot as plt
```

Compare to `matplotlib`

In [20]:
```
import matplotlib.pyplot as plt
```

In [21]:
```
# `matplotlib` is more low-level library
# plots would need more work to be 'prettified'
plt.bar(x = kaggle2020_q1_grouped.index, height = kaggle2020_q1_grouped.values)
```

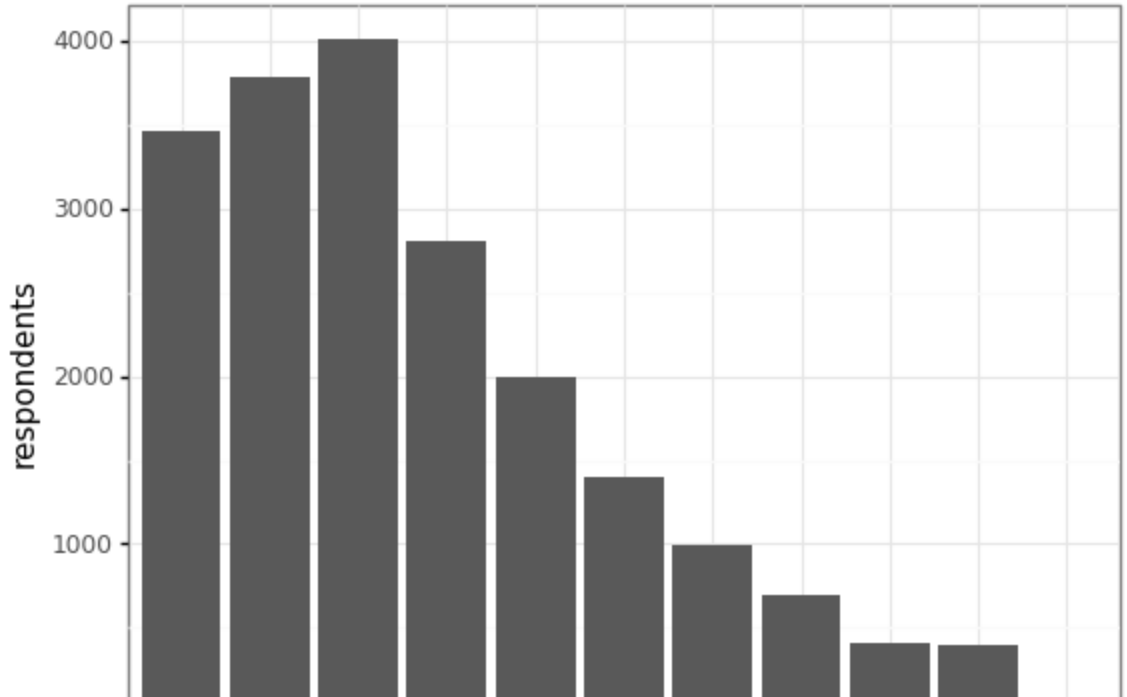
Out[21]:
```
<BarContainer object of 11 artists>
```



Prettifying ggplot in `plotnine`

Prettifying ggplot in `plotnine`

In [22]:
```
# Here we change default axes' labels and then apply B&W theme
q1_plot_pretty = q1_plot +\
    labs(x = 'Age group', y = 'respondents') +\
    theme_bw()
q1_plot_pretty
```



Other geometric objects (`geom_`)

Method	Description
`geom_bar()`, `geom_col()`	Bar charts
`geom_boxplot()`	Box and whisker plot
`geom_histogram()`	Histogram
`geom_point()`	Scatterplot
`geom_line()`, `geom_path()`	Lines
`geom_map()`	Geographic areas
`geom_smooth()`	Smoothed conditional means
`geom_violin()`	Violin plots

Writing plots out in `plotnine`

- Output format is automatically determined from write-out file extension
- Commonly used formats are PDF, PNG and EPS

Writing plots out in `plotnine`

- Output format is automatically determined from write-out file extension
- Commonly used formats are PDF, PNG and EPS

In [23]:
```
q1_plot_pretty.save('../temp/q1_plot_pretty.pdf')
```

```
/home/tpaskhalis/Decrypted/Git/RECSM_2021/venv/lib/python3.8/site-packages/plotn
ine/ggplot.py:719: PlotnineWarning: Saving 6.4 x 4.8 in image.
/home/tpaskhalis/Decrypted/Git/RECSM_2021/venv/lib/python3.8/site-packages/plotn
ine/ggplot.py:722: PlotnineWarning: Filename: ../temp/q1_plot_pretty.pdf
```

Additional visualization materials

Books:

- Hieran, Kiely. 2019. *Data Visualization: A Practical Introduction*. Princeton, NJ: Princeton University Press
- Tufte, Edward. 2001. *The Visual Display of Quantitative Information*. 2nd ed. Cheshire, CT: Graphics Press

Online:

Next

- Linear regression
- Communicating results