Python Code for QSS Chapter 3: Measurement

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First Printing

In Chapter 2, we begin visualizing data. Python has a variety of excellent plotting libraries. This chapter uses seaborn, which is built on top of matplotlib. We occassionally leverage matplotlib to customize plots. In seaborn, we use three families of plotting functions, known as "figure-level" plots in seaborn terminology. Whenever we use one of these function families, we must specify a "kind" of plot, unless the kind we want to use is the default. The table below summarizes the families of plotting functions and the kinds of plots used in this chapter. Seaborn also has more specific, "axes-level," plotting functions, such as `histplot` and `scatterplot`. Axes-level plots are particularly useful for creating sub-plots.

Family	Kind
relplot	scatter (default), line
displot	hist (default), kde
catplot	bar, box

Note: The chapter appendix demonstrates how to customize many of the plots created in this chapter.

Section 3.1: Measuring Civilian Victimization during Wartime

[ ]:
```python
# import libraries used in chapter with conventional aliases
import pandas as pd
import seaborn as sns
import numpy as np
import matplotlib.pyplot as plt

# import data
afghan = pd.read_csv('afghan.csv')

# summarize variables of interest
afghan['age'].describe().round(2)
```

[ ]:
```
count    2754.00
mean       32.39
std        12.29
min        15.00
25%        22.00
50%        30.00
```

```
75%        40.00
max        80.00
Name: age, dtype: float64
```

[ ]:
```
afghan['educ.years'].describe().round(2)
```

[ ]:
```
count    2754.00
mean        4.00
std         4.75
min         0.00
25%         0.00
50%         1.00
75%         8.00
max        18.00
Name: educ.years, dtype: float64
```

[ ]:
```
afghan['employed'].describe().round(2)
```

[ ]:
```
count    2754.00
mean        0.58
std         0.49
min         0.00
25%         0.00
50%         1.00
75%         1.00
max         1.00
Name: employed, dtype: float64
```

[ ]:
```
afghan['income'].describe()
```

[ ]:
```
count              2600
unique                5
top       2,001-10,000
freq               1420
Name: income, dtype: object
```

[ ]:
```
afghan['income'].value_counts(sort=False, dropna=False)
```

[ ]:
```
income
2,001-10,000       1420
NaN                 154
10,001-20,000       616
less than 2,000     457
20,001-30,000        93
over 30,000          14
Name: count, dtype: int64
```

```
[ ]: # convert income to a categorical variable and specify levels
afghan['income'] = afghan['income'].astype('category').cat.reorder_categories(
    ['less than 2,000', '2,001-10,000', '10,001-20,000', '20,001-30,000',
     'over 30,000']
)

afghan['income'].value_counts(sort=False, dropna=False)
```

```
[ ]: income
less than 2,000     457
2,001-10,000       1420
10,001-20,000       616
20,001-30,000        93
over 30,000          14
NaN                 154
Name: count, dtype: int64
```

```
[ ]: pd.crosstab(afghan['violent.exp.ISAF'], afghan['violent.exp.taliban'],
            rownames=['ISAF'], colnames=['Taliban'], normalize=True)
```

```
[ ]: Taliban       0.0       1.0
ISAF
0.0       0.495345  0.131844
1.0       0.176909  0.195903
```

Section 3.2: Handling Missing Data in Pandas

```
[ ]: # print income data for first 10 respondents
afghan['income'].head(10)
```

```
[ ]: 0     2,001-10,000
1     2,001-10,000
2     2,001-10,000
3     2,001-10,000
4     2,001-10,000
5              NaN
6    10,001-20,000
7     2,001-10,000
8     2,001-10,000
9              NaN
Name: income, dtype: category
Categories (5, object): ['less than 2,000', '2,001-10,000', '10,001-20,000',
'20,001-30,000', 'over 30,000']
```

```
[ ]: # indicate whether respondents' income is missing
afghan['income'].isnull().head(10)
```

```
[ ]: 0    False
     1    False
     2    False
     3    False
     4    False
     5     True
     6    False
     7    False
     8    False
     9     True
     Name: income, dtype: bool
```

```
[ ]: # count of missing values
     afghan['income'].isnull().sum()
```

```
[ ]: 154
```

```
[ ]: # proportion of missing values
     afghan['income'].isnull().mean()
```

```
[ ]: 0.05591866376180102
```

```
[ ]: x = pd.Series([1, 2, 3, np.nan])

     # pandas ignores missing values by default
     x.mean()
```

```
[ ]: 2.0
```

```
[ ]: # we can override the default behavior
     x.mean(skipna=False)
```

```
[ ]: nan
```

The pandas `crosstab` method does not have an argument for including missing values in a contingency table. Instead, we can use the `fillna` method to supply a name for the missing values.

```
[ ]: pd.crosstab(afghan['violent.exp.ISAF'].fillna('Nonresponse'),
                 afghan['violent.exp.taliban'].fillna('Nonresponse'),
                 rownames=['ISAF'], colnames=['Taliban'], normalize=True)
```

```
[ ]: Taliban           0.0       1.0  Nonresponse
     ISAF
     0.0          0.482934  0.128540     0.007988
     1.0          0.172476  0.190995     0.007988
     Nonresponse  0.002542  0.002905     0.003631
```

[ ]:
```python
# listwise deletion
afghan_sub = afghan.dropna()

afghan_sub.shape[0]
```

[ ]: 2554

[ ]:
```python
afghan['income'].dropna().shape[0]
```

[ ]: 2600

Section 3.3: Visualizing the Univariate Distribution

Section 3.3.1: Bar Plot

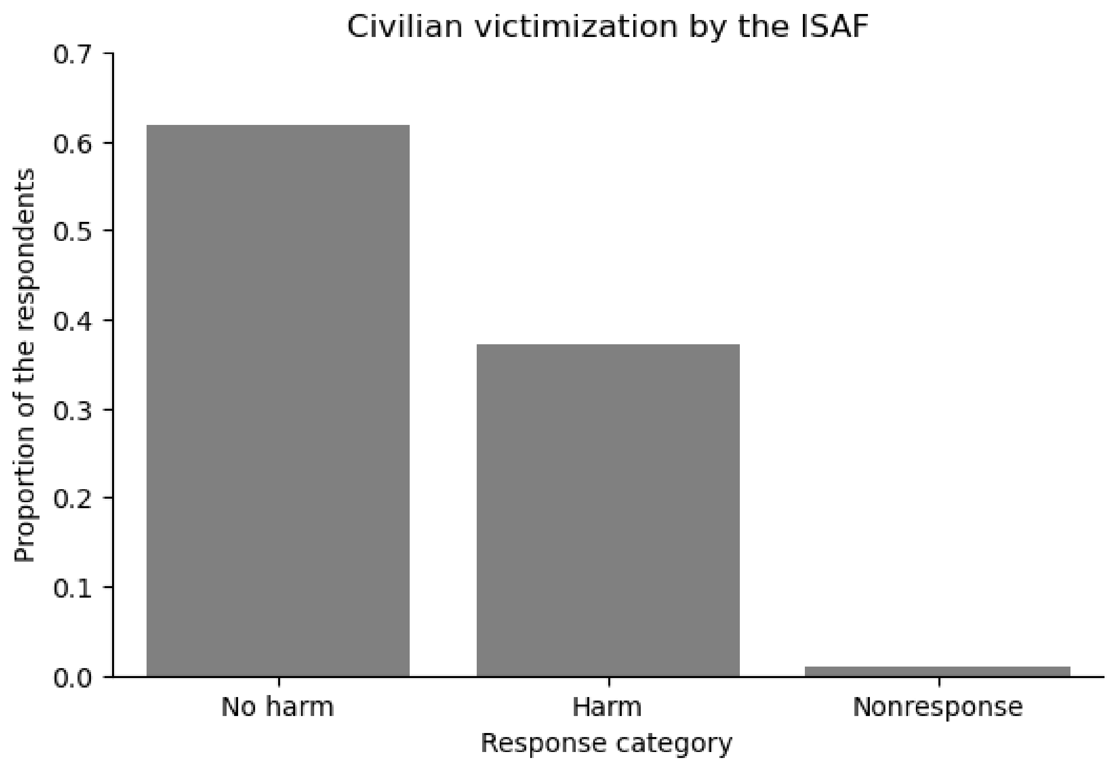
[ ]:
```python
# a vector of proportions to plot
ISAF_ptable = (afghan['violent.exp.ISAF'].
               value_counts(normalize=True, dropna=False).reset_index())

ISAF_ptable
```

[ ]:

	violent.exp.ISAF	proportion
0	0.0	0.619463
1	1.0	0.371460
2	NaN	0.009078

[ ]:
```python
# add a response column for plotting convenience
ISAF_ptable['response'] = ['No harm', 'Harm', 'Nonresponse']

# plot using the catplot family and kind='bar'
sns.catplot(
    data=ISAF_ptable, x='response', y='proportion', color='gray',
    kind='bar', estimator=sum, height=4, aspect=1.5
).set(title='Civilian victimization by the ISAF',
      xlabel='Response category', ylabel='Proportion of the respondents',
      ylim=(0, 0.7))
```

[ ]: <seaborn.axisgrid.FacetGrid at 0x22533ef9cc0>

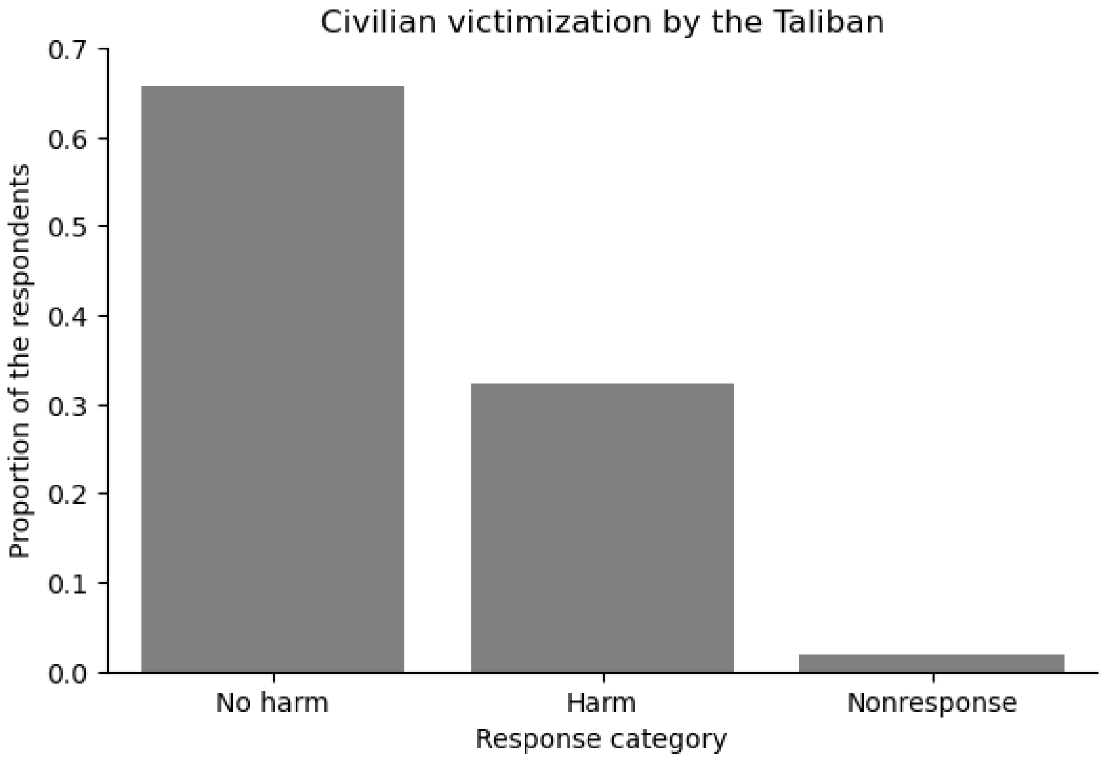


Notice, we use `estimator=sum` because seaborn bar plots aggregate the data by a given function. The default aggregation function is `mean`. Since we have already calculated proportions, we can use `sum` to ensure there is no further aggregation. Another strategy for creating the bar plot is to use the mean aggregation directly on the original data frame categories.

Additionally, we set the height and aspect ratios directly. The default height is 5 inches for seaborn figure-level plots, and the default aspect ratio is 1. The aspect ratio is the ratio of the width to the height. Therefore, the default width is 5 inches.

[ ]:
```
# repeat the same for the Taliban
Taliban_ptable = (afghan['violent.exp.taliban'].
                  value_counts(normalize=True, dropna=False).reset_index())

Taliban_ptable['response'] = ['No harm', 'Harm', 'Nonresponse']

sns.catplot(
    data=Taliban_ptable, x='response', y='proportion', color='gray',
    kind='bar', estimator=sum, height=4, aspect=1.5
).set(title='Civilian victimization by the Taliban',
      xlabel='Response category', ylabel='Proportion of the respondents',
      ylim=(0, 0.7))
```

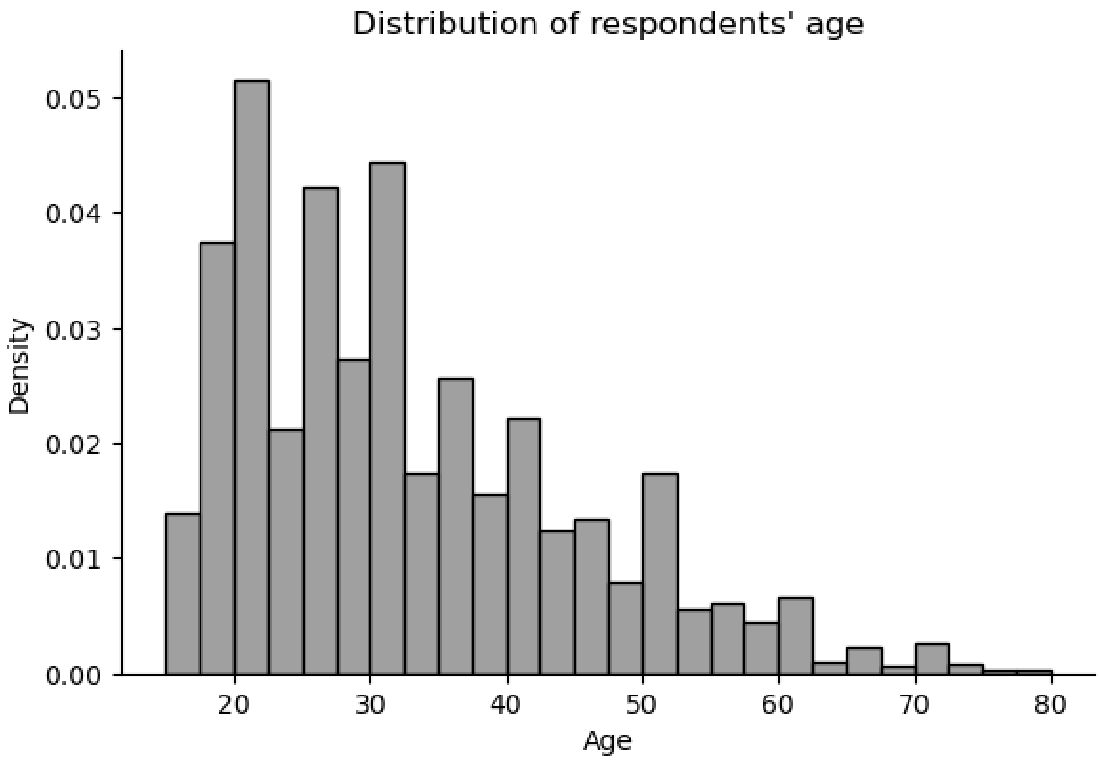
[ ]:
```
<seaborn.axisgrid.FacetGrid at 0x22533ff0070>
```



Section 3.3.2: Histogram

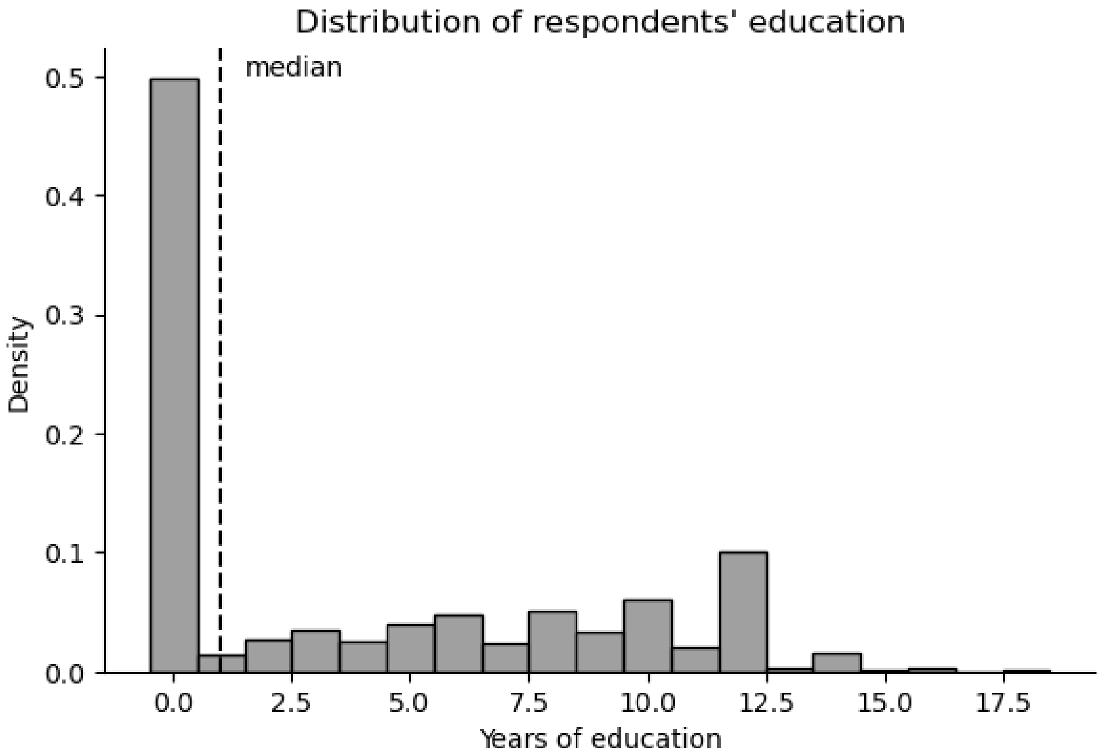
[ ]:
```
sns.displot(
    data=afghan, x='age', stat='density', color='gray',
    height=4, aspect=1.5
).set(title="Distribution of respondents' age", xlabel='Age')
```

[ ]: <seaborn.axisgrid.FacetGrid at 0x22533fa2ef0>



[ ]:
```
# histogram of education
# use binrange and binwidth to control the bins
sns.displot(
    data=afghan, x='educ.years', stat='density', color='gray',
    binrange=(-0.5, 18.5), binwidth=1, height=4, aspect=1.5
).set(title="Distribution of respondents' education",
      xlabel='Years of education')

# add a vertical line representing the median
plt.axvline(x=afghan['educ.years'].median(), color='black', linestyle='--')

# add a text label for the median
plt.text(x=1.5, y=0.5, s='median')
```

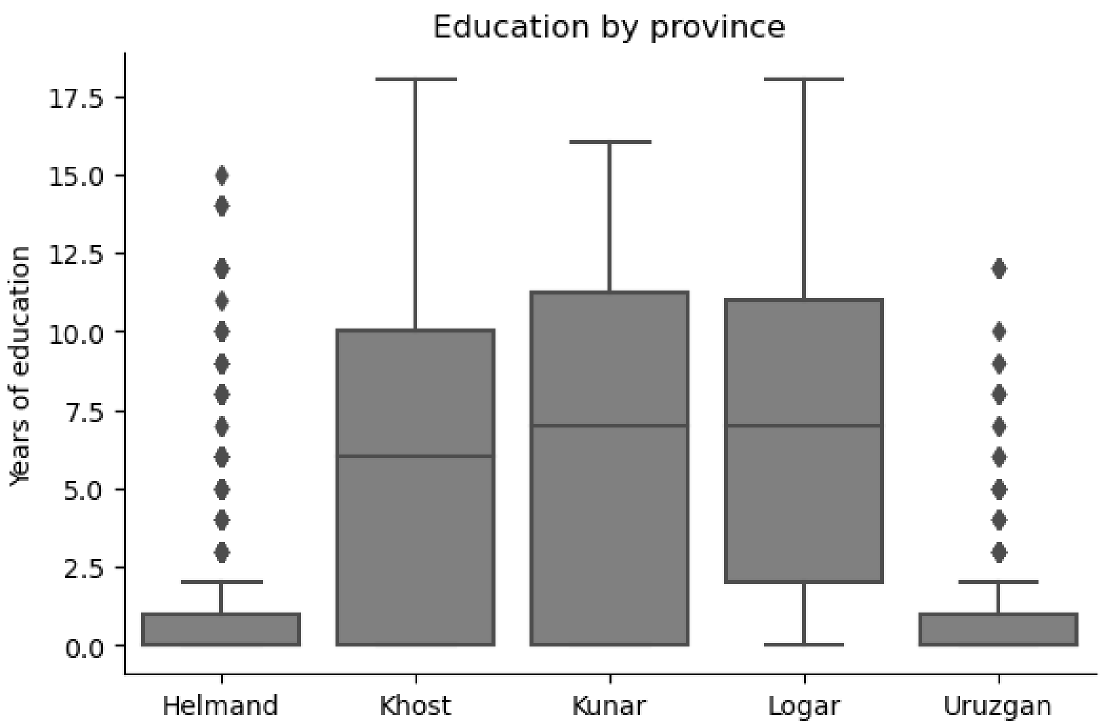
[ ]:
```
Text(1.5, 0.5, 'median')
```



Section 3.3.3: Box Plot

[ ]:
```
# convert province to a categorical variable
# not necessary for plotting, but useful for other analyses
afghan['province'] = afghan['province'].astype('category')

sns.catplot(
    data=afghan, x='province', y='educ.years', kind='box', color='gray',
    height=4, aspect=1.5
).set(title='Education by province', xlabel='', ylabel='Years of education')
```

[ ]:
```
<seaborn.axisgrid.FacetGrid at 0x2253488cd60>
```



[ ]:
```
afghan.groupby('province')['violent.exp.taliban'].mean()
```

[ ]:
```
province
Helmand     0.504222
Khost       0.233227
Kunar       0.303030
Logar       0.080247
Uruzgan     0.454545
Name: violent.exp.taliban, dtype: float64
```

[ ]:
```
afghan.groupby('province')['violent.exp.ISAF'].mean()
```

[ ]:
```
province
Helmand     0.541023
Khost       0.242424
Kunar       0.398990
Logar       0.144033
Uruzgan     0.496042
Name: violent.exp.ISAF, dtype: float64
```

Section 3.3.4: Saving Plots

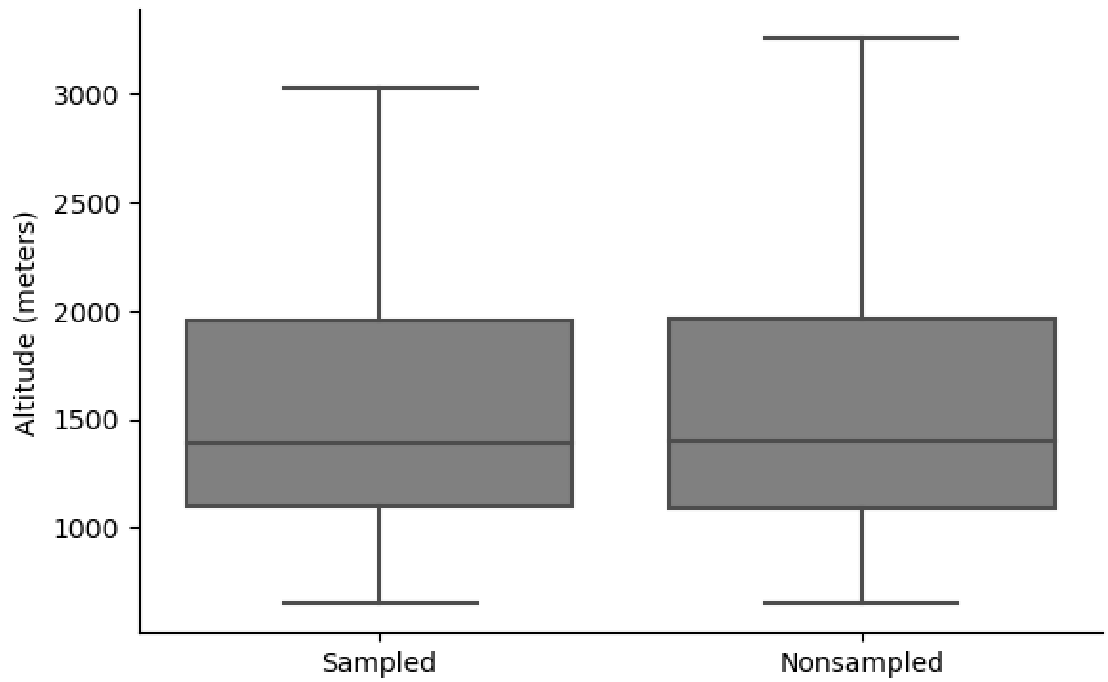
[ ]:
```
# Option 1: Save via point-and-click in IDE

# Option 2: Run plot code plus plt.savefig()

sns.catplot(
    data=afghan, x='province', y='educ.years', kind='box', color='gray',
    height=4, aspect=1.5
).set(title='Education by province', xlabel='', ylabel='Years of education')

plt.savefig('education-by-province.png', bbox_inches='tight')

plt.close() # prevent plot from re-displaying
```

Section 3.4: Survey Sampling

Section 3.4.1: The Role of Randomization

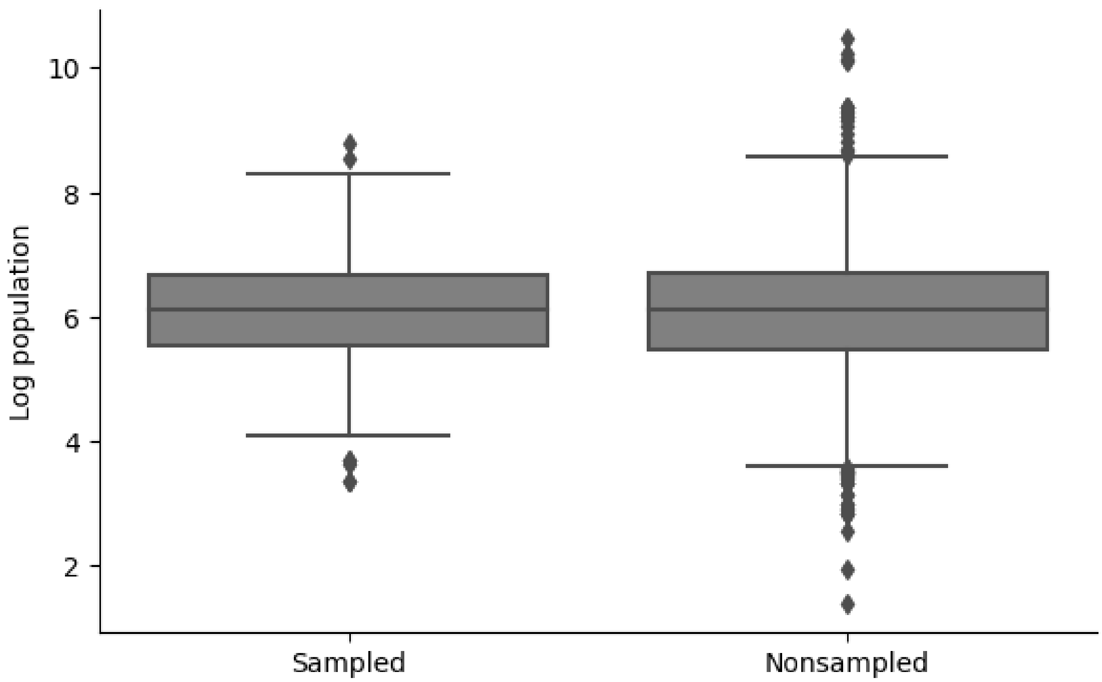
[ ]:
```
# load village data
afghan_village = pd.read_csv('afghan-village.csv')

# add a more descriptive variable for survey status to aid plotting
afghan_village['village_surveyed_desc'] = (
    np.where(afghan_village['village.surveyed']==1, 'Sampled', 'Nonsampled')
    )

# boxplots for altitude
sns.catplot(
    data=afghan_village, x='village_surveyed_desc', y='altitude', kind='box',
    color='gray', height=4, aspect=1.5
).set(ylabel='Altitude (meters)', xlabel='')
```

[ ]:
```
<seaborn.axisgrid.FacetGrid at 0x22535a376d0>
```




```
[ ]: # add the natural log of population to the data frame
afghan_village['log_pop'] = np.log(afghan_village['population'])

# boxplots for log population
sns.catplot(
    data=afghan_village, x='village_surveyed_desc', y='log_pop', kind='box',
    color='gray', height=4, aspect=1.5
).set(ylabel='Log population', xlabel='')
```

```
[ ]: <seaborn.axisgrid.FacetGrid at 0x22535a37070>
```



Section 3.4.2: Nonresponse and Other Sources of Bias

[ ]:
```
afghan.groupby('province')['violent.exp.taliban'].apply(
    lambda x: x.isnull().mean()
)
```

[ ]:
```
province
Helmand    0.030409
Khost      0.006349
Kunar      0.000000
Logar      0.000000
Uruzgan    0.062016
Name: violent.exp.taliban, dtype: float64
```

[ ]:
```
afghan.groupby('province')['violent.exp.ISAF'].apply(
    lambda x: x.isnull().mean()
)
```

[ ]:
```
province
Helmand    0.016374
Khost      0.004762
Kunar      0.000000
Logar      0.000000
Uruzgan    0.020672
```

```
Name: violent.exp.ISAF, dtype: float64
```

[ ]:
```
(afghan['list.response'][afghan['list.group'] == 'ISAF'].mean() -
 afghan['list.response'][afghan['list.group'] == 'control'].mean())
```

[ ]:
```
0.0490196078431373
```

[ ]:
```
afghan['list.group'] = (
    afghan['list.group'].astype('category').cat.reorder_categories(
        ['control', 'ISAF', 'taliban'])
)

pd.crosstab(afghan['list.response'], afghan['list.group'],
            colnames=['group'], rownames=['response'])
```

[ ]:
```
group     control  ISAF  taliban
response
0             188   174        0
1             265   278      433
2             265   260      287
3             200   182      198
4               0    24        0
```

Section 3.5: Measuring Political Polarization

Section 3.6: Summarizing Bivariate Relationships

Section 3.6.1: Scatter Plot

[ ]:
```
congress = pd.read_csv('congress.csv')

congress.head()
```

[ ]:
```
   congress  district    state     party        name  dwnom1  dwnom2
0        80         0      USA  Democrat      TRUMAN  -0.276   0.016
1        80         1  ALABAMA  Democrat  BOYKIN  F.  -0.026   0.796
2        80         2  ALABAMA  Democrat   GRANT  G.  -0.042   0.999
3        80         3  ALABAMA  Democrat ANDREWS  G.  -0.008   1.005
4        80         4  ALABAMA  Democrat   HOBBS  S.  -0.082   1.066
```

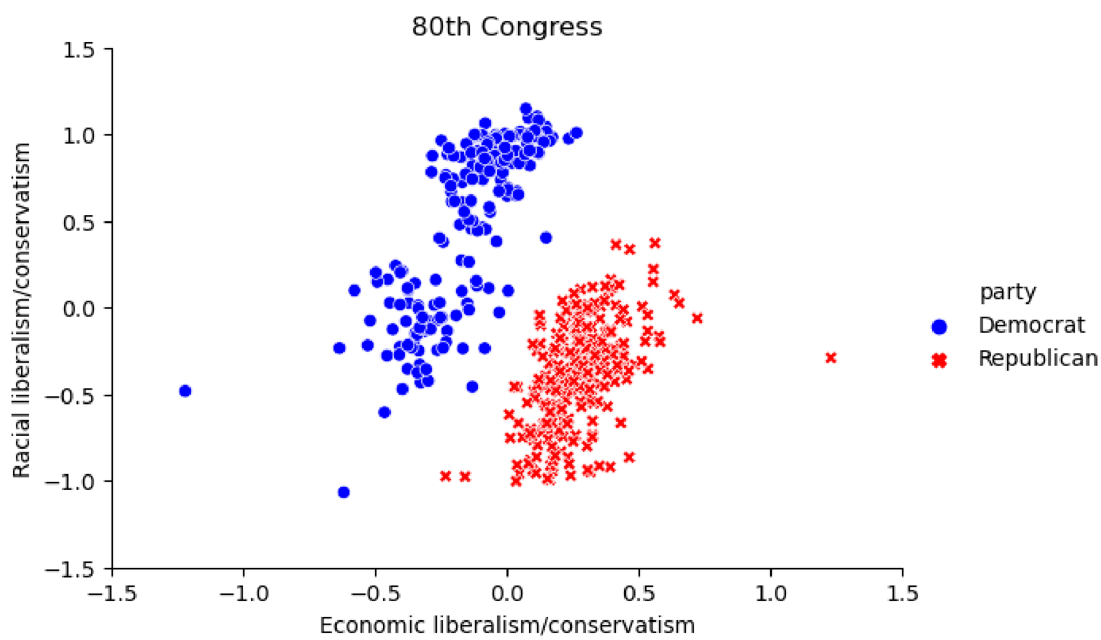
[ ]:
```
congress.dtypes
```

[ ]:
```
congress      int64
district      int64
state        object
party        object
name         object
dwnom1      float64
dwnom2      float64
```

```
dtype: object
```

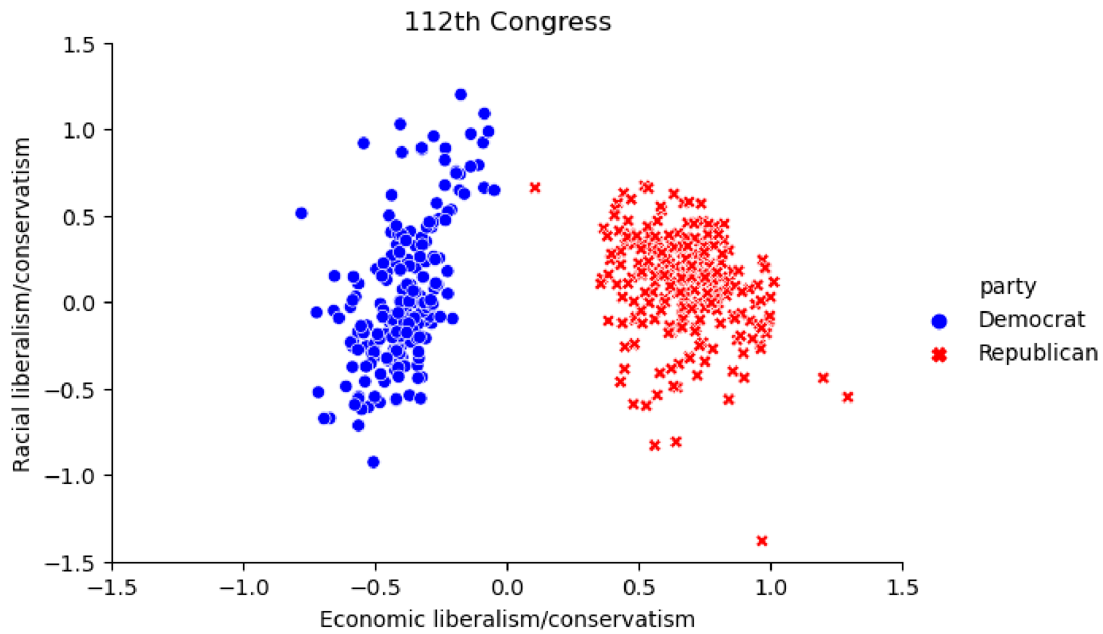
[ ]:
```python
# store some plotting parameters for reuse
xlab='Economic liberalism/conservatism'
ylab='Racial liberalism/conservatism'
lim=(-1.5, 1.5)

# scatterplot for 80th congress
sns.relplot(
    data=congress.loc[(congress['congress'] == 80) &
                      (congress['party'] != 'Other')],
    x='dwnom1', y='dwnom2', hue='party', style='party', palette=['b', 'r'],
    height=4, aspect=1.5
).set(title='80th Congress', xlabel=xlab, ylabel=ylab, xlim=lim, ylim=lim)
```

[ ]:
```
<seaborn.axisgrid.FacetGrid at 0x22535aedf00>
```



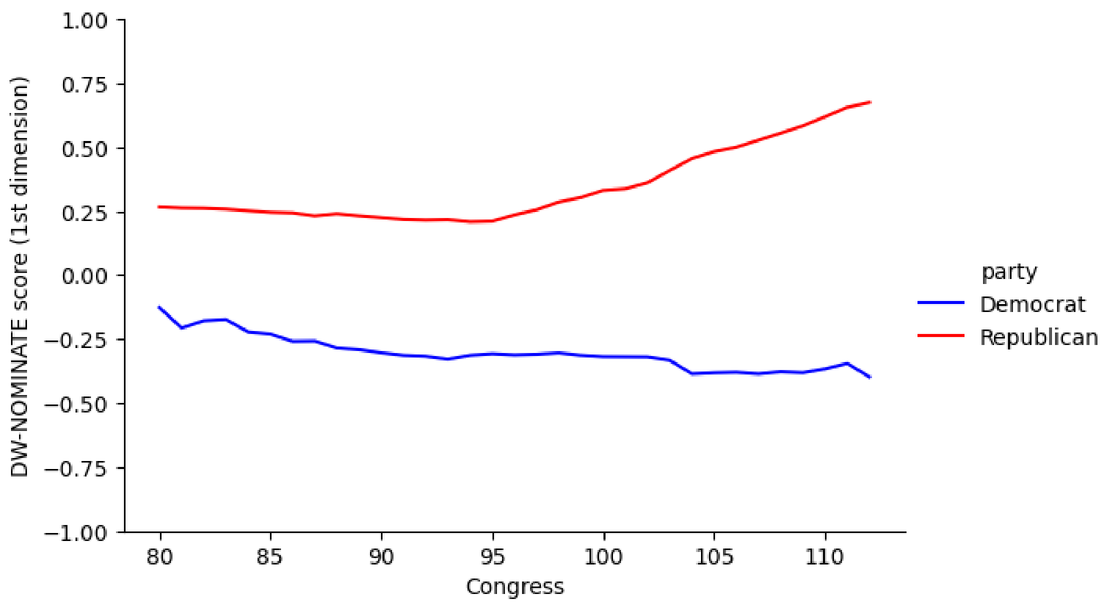
[ ]:
```python
# scatterplot for 112th congress
sns.relplot(
    data=congress.loc[(congress['congress'] == 112) &
                      (congress['party'] != 'Other')],
    x='dwnom1', y='dwnom2', hue='party', style='party', palette=['b', 'r'],
    height=4, aspect=1.5
).set(title='112th Congress', xlabel=xlab, ylabel=ylab, xlim=lim, ylim=lim)
```

[ ]:
```
<seaborn.axisgrid.FacetGrid at 0x22535a37cd0>
```



[ ]:
```
# Find the median for combinations of party and congress
dwn1_med = (congress.loc[congress.party != 'Other'].
            groupby(['party', 'congress'])['dwnom1'].median().reset_index())

sns.relplot(
    data=dwn1_med, x='congress', y='dwnom1', hue='party', kind='line',
    palette=['b', 'r'], height=4, aspect=1.5
).set(ylim=(-1, 1), xlabel='Congress',
      ylabel='DW-NOMINATE score (1st dimension)')
```

[ ]:
```
<seaborn.axisgrid.FacetGrid at 0x22535c86d40>
```



Section 3.6.2: Correlation

[ ]:
```
gini = pd.read_csv('USGini.csv')

'''
Calculate the difference between the Republican and Democratic medians.

pandas will try to align indexes in conducting vector arithmetic. Therefore,
it is best to reset the index and drop the old one so that the indexes are the
same. An alternative is to use numpy arrays.
'''
med_diff = (
    dwn1_med['dwnom1'][dwn1_med.party=='Republican'].reset_index(drop=True) -
    dwn1_med['dwnom1'][dwn1_med.party=='Democrat'].reset_index(drop=True)
)

# time series plot for partisan differences
# notice, we can feed x and y directly
sns.relplot(
    x=np.arange(1947.5, 2012.5, step=2), y=med_diff, kind='line',
    color='black', height=4, aspect=1.5
).set(title='Political Polarization', xlabel='Year',
      ylabel='Republican median - Democratic median')
```

[ ]:
```
<seaborn.axisgrid.FacetGrid at 0x22535da7910>
```

[ ]:
```
# time-series plot for Gini coefficient
sns.relplot(
    data=gini, x='year', y='gini', kind='line', color='black',
    height=4, aspect=1.5
).set(title='Income Inequality', ylabel='Gini coefficient', xlabel='Year')
```

[ ]:
```
<seaborn.axisgrid.FacetGrid at 0x22535f77a60>
```

To correlate the partisan difference with the Gini coefficient, we need to select every other observation for the Gini starting with the second observation.

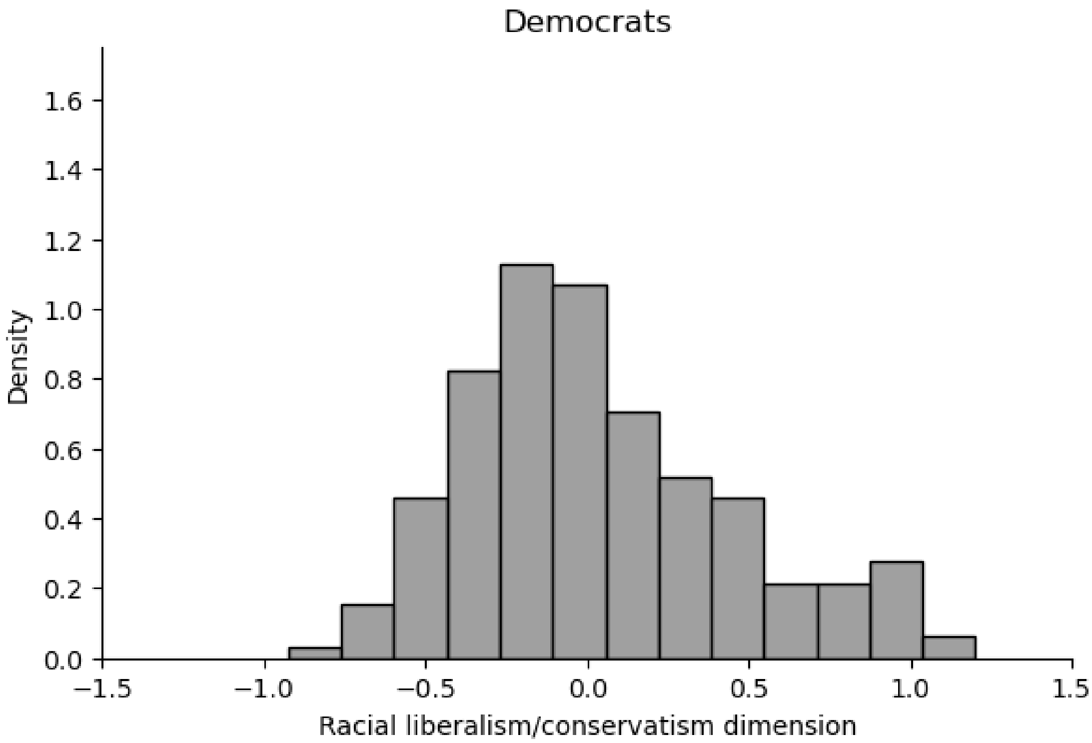
[ ]:
```
(gini['gini'].iloc[np.arange(1, gini.shape[0], step=2)].
 reset_index(drop=True).corr(med_diff))
```

[ ]: 0.9418128160619333

Section 3.6.3: Quantile-Quantile Plot

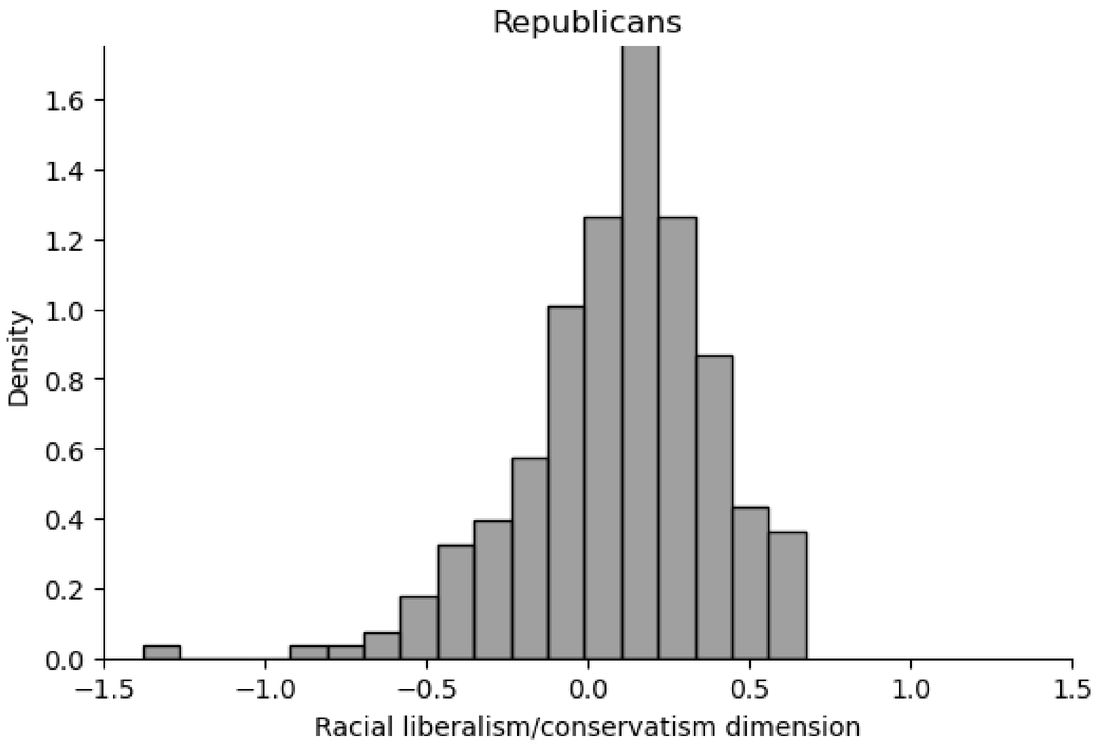
[ ]:
```
dem112 = congress.loc[(congress['congress'] == 112) &
                      (congress['party'] == 'Democrat')]

rep112 = congress.loc[(congress['congress'] == 112) &
                      (congress['party'] == 'Republican')]

sns.displot(
    data=dem112, x='dwnom2', stat='density', color='gray',
    height=4, aspect=1.5
).set(title='Democrats', xlabel='Racial liberalism/conservatism dimension',
      xlim=(-1.5, 1.5), ylim=(0, 1.75))
```

[ ]: <seaborn.axisgrid.FacetGrid at 0x22535ff5750>




```
[ ]: sns.displot(
         data=rep112, x='dwnom2', stat='density', color='gray',
         height=4, aspect=1.5
     ).set(title='Republicans', xlabel='Racial liberalism/conservatism dimension',
           xlim=(-1.5, 1.5), ylim=(0, 1.75))
```

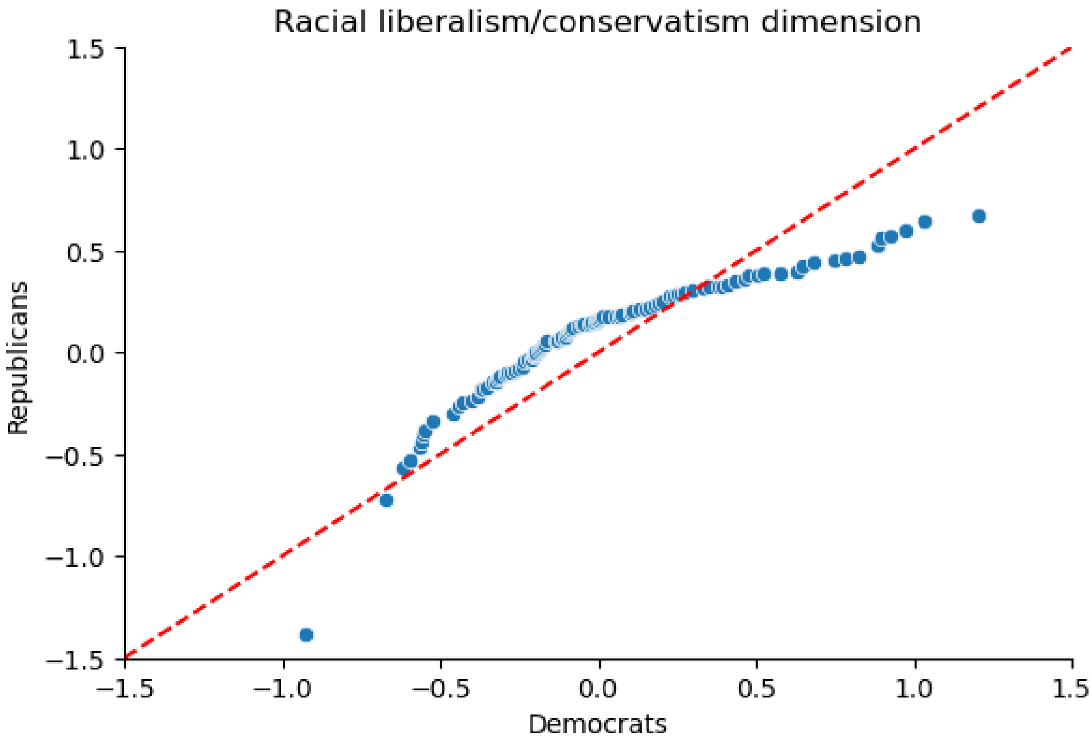
```
[ ]: <seaborn.axisgrid.FacetGrid at 0x22537134610>
```



Seaborn does not have a built-in function for Q-Q plots. However, we can create a scatterplot of the quantiles of two variables. The quantiles we plot need to be the same length. Below, we calculate and plot percentiles.

[ ]:
```
quantiles = np.linspace(0, 1, 101)

demq = dem112['dwnom2'].quantile(quantiles)
repq = rep112['dwnom2'].quantile(quantiles)

sns.relplot(
    x = demq, y = repq, height=4, aspect=1.5
).set(xlabel='Democrats', ylabel='Republicans',
      title='Racial liberalism/conservatism dimension',
      ylim=(-1.5, 1.5), xlim=(-1.5, 1.5))

plt.gca().axline((0, 0), slope=1, color='red', linestyle='--')
```

[ ]:
```
<matplotlib.lines._AxLine at 0x225377a3a90>
```



Section 3.7: Clustering

Before implementing clustering with the k-Means algorithm, we discuss numpy arrays and objects in Python, both of which are important for many Python modeling libraries.

Section 3.7.1: Numpy Arrays

Thus far, we have used the numpy library for specific tasks, such as vectorized if-else statements using `np.where()` and log transformations using `np.log()`, but we have primarily relied on pandas for our analytical infrastructure. Understanding how numpy works is important for effective data analytics in Python. Indeed, pandas is built on top of numpy. While Python modeling libraries often work well with pandas, they occasionally work better with numpy, and many modeling outputs are numpy objects, as we will see in 3.7.3.

The fundamental numpy data structure is the N-dimensional array, known as the `ndarray`. For those coming from an R background, a one-dimensional numpy array is similar to a vector in R. There are a number of ways to create a numpy vector, depending on the analytical context.

[ ]:
```
# One-dimensional arrays as vectors

# create a one-dimensional numpy array

## from a list
x = np.array([10, 20, 30, 40, 50])
```

```
x
```

[ ]: array([10, 20, 30, 40, 50])

```
## from a sequence
y = np.arange(10, 60, 10)

y
```

[ ]: array([10, 20, 30, 40, 50])

```
## from random draws from a uniform distribution between 50 and 100
z = np.random.uniform(low=50, high=100, size=10)

z
```

```
array([56.87441857, 91.88108259, 60.69070475, 56.30115992, 62.14235899,
       74.82719271, 86.16706291, 84.03827682, 87.39209682, 76.89900154])
```

Indexing and slicing numpy arrays is similar to indexing and slicing Python lists.

```
# select the first observation from z
## recall, Python uses zero-based indexing
z[0]
```

[ ]: 56.8744185658357

```
# select the first five observations from z
## recall, Python uses "up to but not including" slicing semantics
z[0:5]
```

[ ]: array([56.87441857, 91.88108259, 60.69070475, 56.30115992, 62.14235899])

```
# select the fifth observation onward
z[4:]
```

```
array([62.14235899, 74.82719271, 86.16706291, 84.03827682, 87.39209682,
       76.89900154])
```

In base Python, we need to use for loops to perform operations on each element of a list. Numpy, by contrast, enables vectorized computations.

```
# conduct vectorized arithmetic: multiply each element by .25
z * .25
```

```
array([14.21860464, 22.97027065, 15.17267619, 14.07528998, 15.53558975,
       18.70679818, 21.54176573, 21.0095692 , 21.8480242 , 19.22475039])
```

[ ]:
```
# conduct conditional vectorized arithmetic
## if an element is above 75, multiply by .25; otherwise, multiply by .75
np.where(z > 75, z * .25, z * .75)
```

[ ]:
```
array([42.65581392, 22.97027065, 45.51802857, 42.22586994, 46.60676924,
       56.12039453, 21.54176573, 21.0095692 , 21.8480242 , 19.22475039])
```

[ ]:
```
# calculate the sum of the elements
z.sum()
```

[ ]:
```
737.2133556365816
```

[ ]:
```
# calculate the mean of the elements
z.mean()
```

[ ]:
```
73.72133556365816
```

Two-dimensional numpy arrays can be thought of as matrices.

[ ]:
```
# create a two-dimensional numpy array from a range
mat = np.arange(0, 10).reshape(5, 2)

mat
```

[ ]:
```
array([[0, 1],
       [2, 3],
       [4, 5],
       [6, 7],
       [8, 9]])
```

[ ]:
```
# select the first row
mat[0]
```

[ ]:
```
array([0, 1])
```

[ ]:
```
# select the second column
mat[:,1]
```

[ ]:
```
array([1, 3, 5, 7, 9])
```

[ ]:
```
# select the first two rows and the second column
mat[0:2, 1]
```

[ ]:
```
array([1, 3])
```

[ ]:
```
# calculate the sum of the columns
mat.sum(axis=0)
```

[ ]:
```
array([20, 25])
```

```
[ ]: # calculate the mean of the rows
     mat.mean(axis=1)
```

```
[ ]: array([0.5, 2.5, 4.5, 6.5, 8.5])
```

```
[ ]: # calculate the standard deviation of the columns
     mat.std(axis=0)
```

```
[ ]: array([2.82842712, 2.82842712])
```

If we intend to treat a two-dimensional numpy array as a matrix, then the array must have the same data type for all elements. A data frame can have different data types for each column.

```
[ ]: df = pd.DataFrame({'x': ['a', 'b', 'c'], 'y': [1, 2, 3]})

     df.dtypes # contains a string and an integer
```

```
[ ]: x    object
     y     int64
     dtype: object
```

```
[ ]: # convert the data frame to a numpy array
     np.array(df)
```

```
[ ]: array([['a', 1],
            ['b', 2],
            ['c', 3]], dtype=object)
```

Converting a data frame with heterogeneous data types to a numpy array produces a complex data structure that is effectively an array of Python lists. The overall data type is 'object,' but each list contains a string and an integer. The data structure is not a matrix, and should not be treated as such.

Python lists can contain different data types. If we try to convert a single list containing an integers and strings to a numpy array, the integers will be converted to strings.

```
[ ]: np.array([1, 2, 'a', 'b'])
```

```
[ ]: array(['1', '2', 'a', 'b'], dtype='<U11')
```

In many cases, modeling libraries accept pandas data structures directly. Often, on the back end, the libraries are converting the pandas objects to numpy arrays. In some cases, though, modeling routines require numpy arrays as inputs. For these cases, pandas has a convenience method `to_numpy()` that converts a data frame to a numpy array. Consistent with the illustration above, the method is meant to be used with homogenous data types.

Section 3.7.2: Objects in Python

In Python, it is said that "everything is an object." Python makes heavy use of object oriented programming (OOP), a programming paradigm that involves grouping code and data together into objects. In OOP, an object is created from a template called a "class." The data associated with objects are generally called attributes, and the functions are called methods. Libraries like pandas, numpy, and seaborn are designed so that we do not have to worry too much about OOP particulars. Still, it is important to recognize that we are working with objects of specific classes that have attributes and methods.

[ ]:
```
# check the object class
type(congress)
```

[ ]:
```
pandas.core.frame.DataFrame
```

[ ]:
```
# review an object's methods and attributes; print the first 15
dir(congress)[0:15]
```

[ ]:
```
['T',
 '_AXIS_LEN',
 '_AXIS_ORDERS',
 '_AXIS_TO_AXIS_NUMBER',
 '_HANDLED_TYPES',
 '__abs__',
 '__add__',
 '__and__',
 '__annotations__',
 '__array__',
 '__array_priority__',
 '__array_ufunc__',
 '__bool__',
 '__class__',
 '__contains__']
```

[ ]:
```
# use a list comprehension to view the non-private attributes and methods
[item for item in dir(congress) if not item.startswith('_')][0:15]
```

[ ]:
```
['T',
 'abs',
 'add',
 'add_prefix',
 'add_suffix',
 'agg',
 'aggregate',
 'align',
 'all',
 'any',
 'apply',
 'applymap',
 'asfreq',
 'asof',
 'assign']
```

```
[ ]: # use the data frame's value_counts "method"
     congress['party'].value_counts()
```

```
[ ]: party
     Democrat      8132
     Republican    6401
     Other           19
     Name: count, dtype: int64
```

```
[ ]: # review the data frame's shape "attribute"
     congress.shape
```

```
[ ]: (14552, 7)
```

As we will see in 3.7.3, some important modeling libraries in Python rely on a more conventional OOP workflow. In such a workflow, one generally follows a few key steps:

- Select a class.
- Instantiate an object of the class and set desired parameters.
- Use the object's methods to perform operations on data.
- Extract results from the object.

Section 3.7.3: The k-Means Algorithm

```
[ ]: from sklearn.cluster import KMeans

     dwnom80 = congress.loc[congress['congress']==80, ['dwnom1', 'dwnom2']].copy()

     dwnom112 = congress.loc[congress['congress']==112, ['dwnom1', 'dwnom2']].copy()

     # kmeans with two clusters

     ## instantiate the model with parameters
     k80two = KMeans(n_clusters=2, n_init=5)
     k112two = KMeans(n_clusters=2, n_init=5)
```

If you are working on Windows, you may get a warning about about memory leakage associated with using KMeans on Windows. The warning will likely recommend setting the environmental variable OPM_NUM_THREADS to a certain value. To do so, follow these steps:

- (1) Click on the Windows Search button
- (2) Type "Edit the system environment variables"
- (3) Select "Environment Variables"
- (4) Click "New" under "User variables for your_username"
- (5) Enter "OMP_NUM_THREADS" for the variable name and '1' or the number recommended in the warning for the variable value
- (6) Click "OK" and close the windows

[ ]:
```
## fit the model to the data
k80two.fit(dwnom80)
k112two.fit(dwnom112)

## predict the clusters
k80two_labels = k80two.predict(dwnom80)
k112two_labels = k112two.predict(dwnom112)

type(k80two_labels) # numpy.ndarray
```

[ ]:
```
numpy.ndarray
```

[ ]:
```
# Use a list comprehension to view the non-private methods and attributes
[item for item in dir(k80two) if not item.startswith('_')]
```

[ ]:
```
['algorithm',
 'cluster_centers_',
 'copy_x',
 'feature_names_in_',
 'fit',
 'fit_predict',
 'fit_transform',
 'get_feature_names_out',
 'get_params',
 'inertia_',
 'init',
 'labels_',
 'max_iter',
 'n_clusters',
 'n_features_in_',
 'n_init',
 'n_iter_',
 'predict',
 'random_state',
 'score',
 'set_output',
 'set_params',
 'tol',
 'transform',
 'verbose']
```

[ ]:
```
# final centroids
k80two.cluster_centers_
```

[ ]:
```
array([[ 0.15212662, -0.34353896],
       [-0.05605797,  0.76863044]])
```

[ ]:
```
k112two.cluster_centers_
```

[ ]: array([[0.6753251 , 0.09296708],
       [-0.39376   , 0.029455]])

[ ]:
```
type(k112two.cluster_centers_) # numpy.ndarray
```

[ ]: numpy.ndarray

[ ]:
```
# number of observations for each cluster by party
pd.crosstab(congress['party'][congress.congress == 80],
            k80two_labels, colnames=['cluster'])
```

[ ]:

cluster	0	1
party		
Democrat	59	135
Other	2	0
Republican	247	3

[ ]:
```
pd.crosstab(congress['party'][congress.congress == 112],
            k112two_labels, colnames=['cluster'])
```

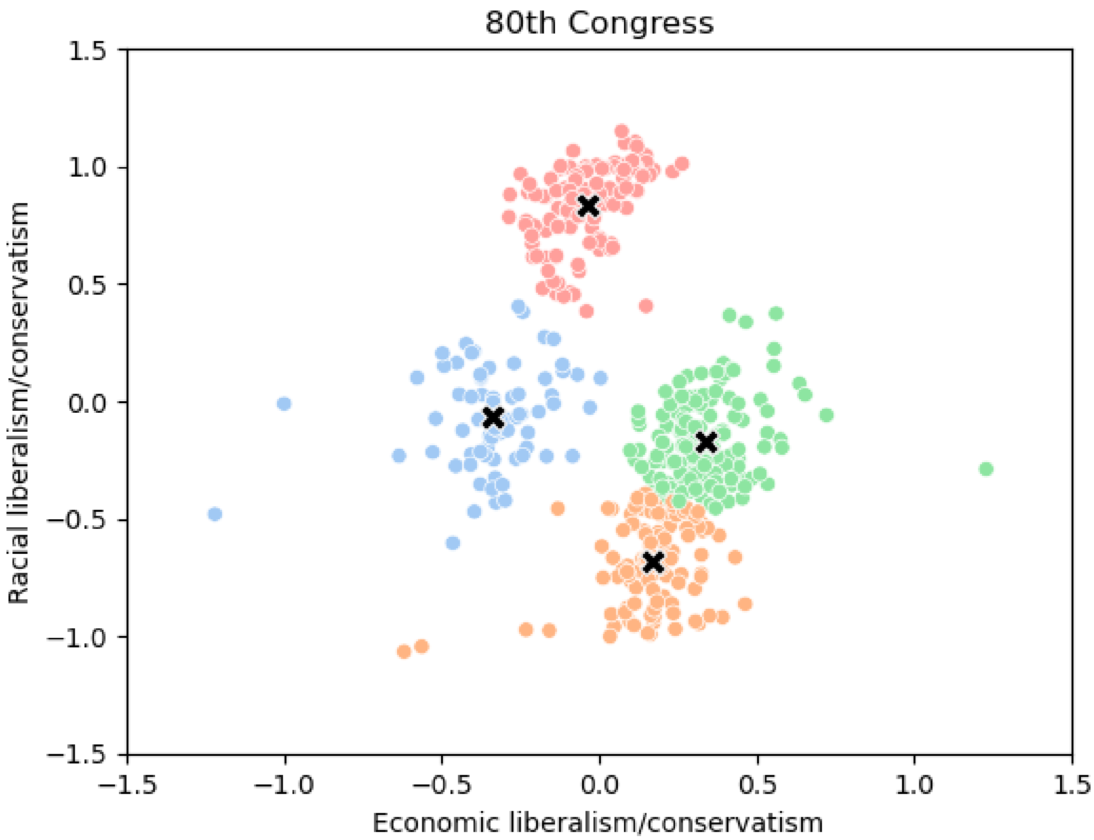
[ ]:

cluster	0	1
party		
Democrat	0	200
Republican	243	0

[ ]:
```
# k means with four clusters
k80four = KMeans(n_clusters=4, n_init=5)
k112four = KMeans(n_clusters=4, n_init=5)

k80four.fit(dwnom80)
k112four.fit(dwnom112)

k80four_labels = k80four.predict(dwnom80)
k112four_labels = k112four.predict(dwnom112)
```

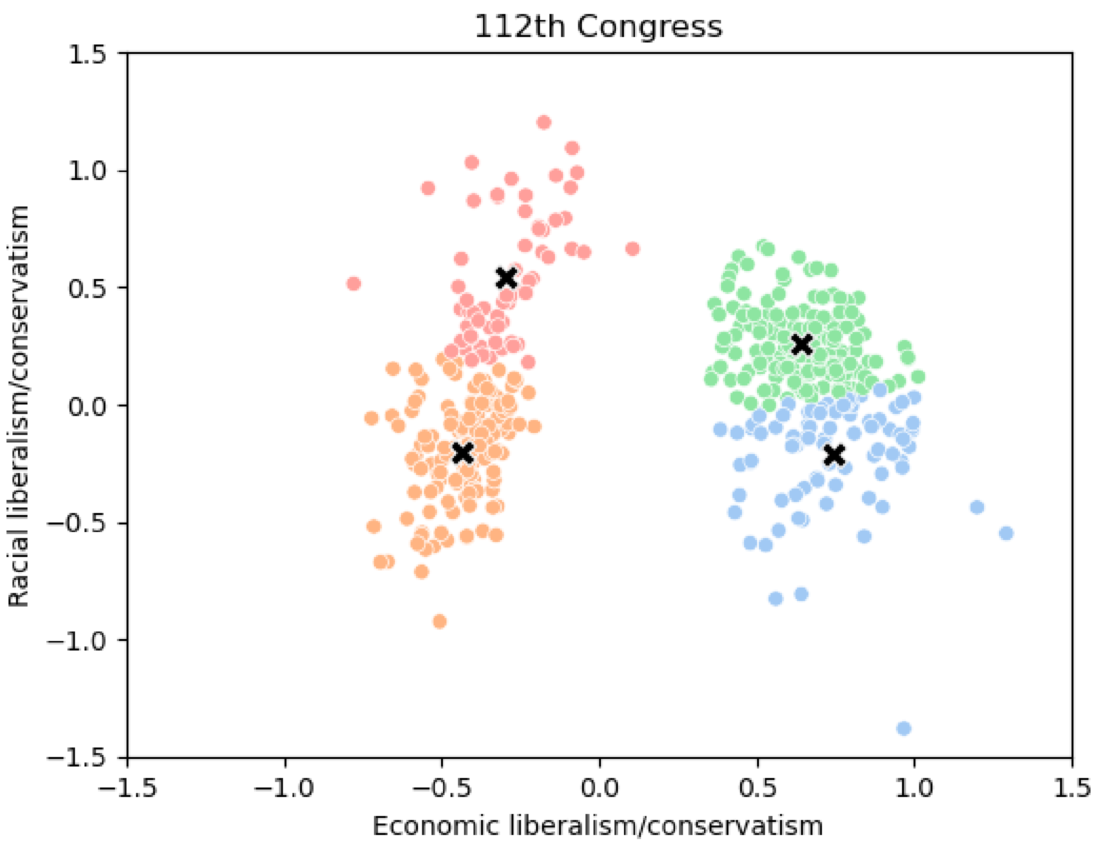
[ ]:
```
# plot the centroids over the clusters using subplots
fix, ax = plt.subplots(1,1)

sns.scatterplot(
    data=dwnom80, x='dwnom1', y='dwnom2', hue=k80four_labels, legend=False,
    palette='pastel', ax=ax,
    ).set(title='80th Congress', xlabel=xlab, ylabel=ylab, xlim=lim, ylim=lim)

sns.scatterplot(
    x=k80four.cluster_centers_[:,0], y=k80four.cluster_centers_[:,1],
    legend=False, color='black', s=100, marker='X', ax=ax,
    )
```

[ ]: <Axes: title={'center': '80th Congress'}, xlabel='Economic liberalism/conservatism', ylabel='Racial liberalism/conservatism'>



[ ]:
```
# repeat for 112th congress
fix, ax = plt.subplots(1,1)

sns.scatterplot(
    data=dwnom112, x='dwnom1', y='dwnom2', hue=k112four_labels, legend=False,
    palette='pastel', ax=ax,
    ).set(title='112th Congress', xlabel=xlab, ylabel=ylab, xlim=lim, ylim=lim)

sns.scatterplot(
    x=k112four.cluster_centers_[:,0], y=k112four.cluster_centers_[:,1],
    legend=False, color='black', s=100, marker='X', ax=ax,
    )
```

[ ]: <Axes: title={'center': '112th Congress'}, xlabel='Economic liberalism/conservatism', ylabel='Racial liberalism/conservatism'>



Appendix: Customizing Plots

This appendix demonstrates how to use themes, sub-plots, facets, and groupings to compare distributions and relationships.

Section A.1: Grouped Bar Plot

[ ]:
```
# Recall the univariate distributions
ISAF_ptable
```

[ ]:

	violent.exp.ISAF	proportion	response
0	0.0	0.619463	No harm
1	1.0	0.371460	Harm
2	NaN	0.009078	Nonresponse

[ ]:
```
Taliban_ptable
```

[ ]:

	violent.exp.taliban	proportion	response
0	0.0	0.657952	No harm
1	1.0	0.322440	Harm

```
2                   NaN    0.019608  Nonresponse
```

We can view these distributions side-by-side in a barplot using groupings. Grouped visualizations work best in seaborn when the grouping variable is in its own column.

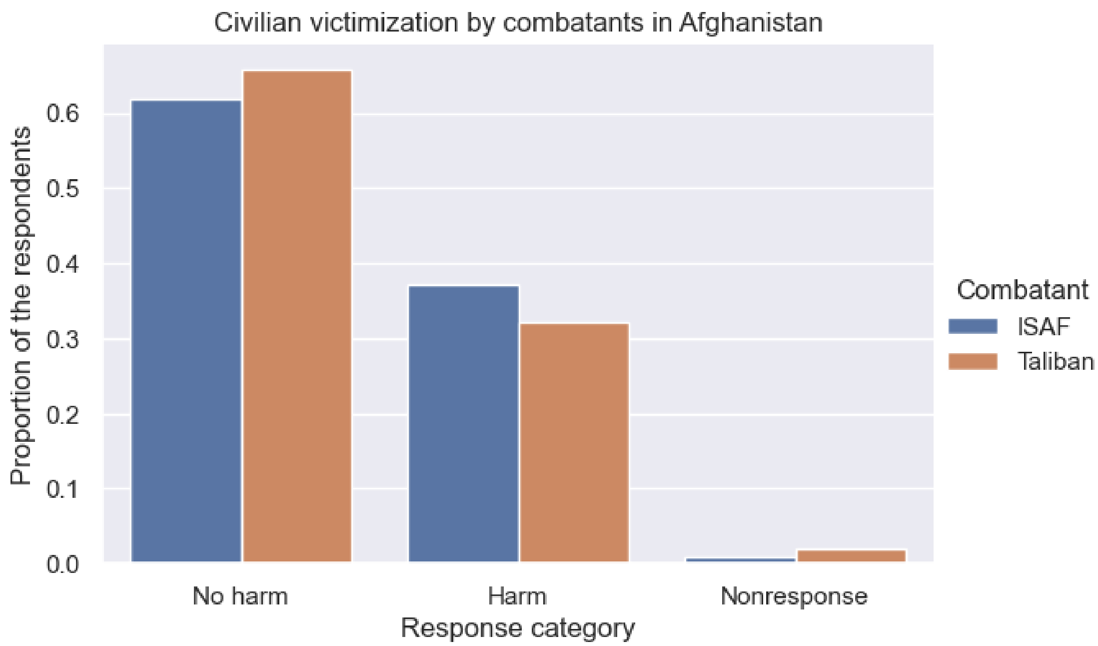
```
[ ]: # add an identifer for combatant (the grouping variable)
ISAF_ptable['Combatant'] = 'ISAF'
Taliban_ptable['Combatant'] = 'Taliban'

# stack the two data frames using concatenation; leave out the first column
combatants_ptable = pd.concat([ISAF_ptable.iloc[:,1:],
                               Taliban_ptable.iloc[:,1:]], axis=0)

combatants_ptable
```

```
[ ]:    proportion     response Combatant
0    0.619463      No harm      ISAF
1    0.371460         Harm      ISAF
2    0.009078  Nonresponse      ISAF
0    0.657952      No harm   Taliban
1    0.322440         Harm   Taliban
2    0.019608  Nonresponse   Taliban
```

Use the `hue` argument to specify the grouping variable and distinguish the groups by color.

```
[ ]: sns.set_theme(style="darkgrid")

sns.catplot(
    data=combatants_ptable, x='response', y='proportion', kind='bar',
    estimator=sum, hue='Combatant', height=4, aspect=1.5
).set(xlabel='Response category', ylabel='Proportion of the respondents',
      title='Civilian victimization by combatants in Afghanistan')
```

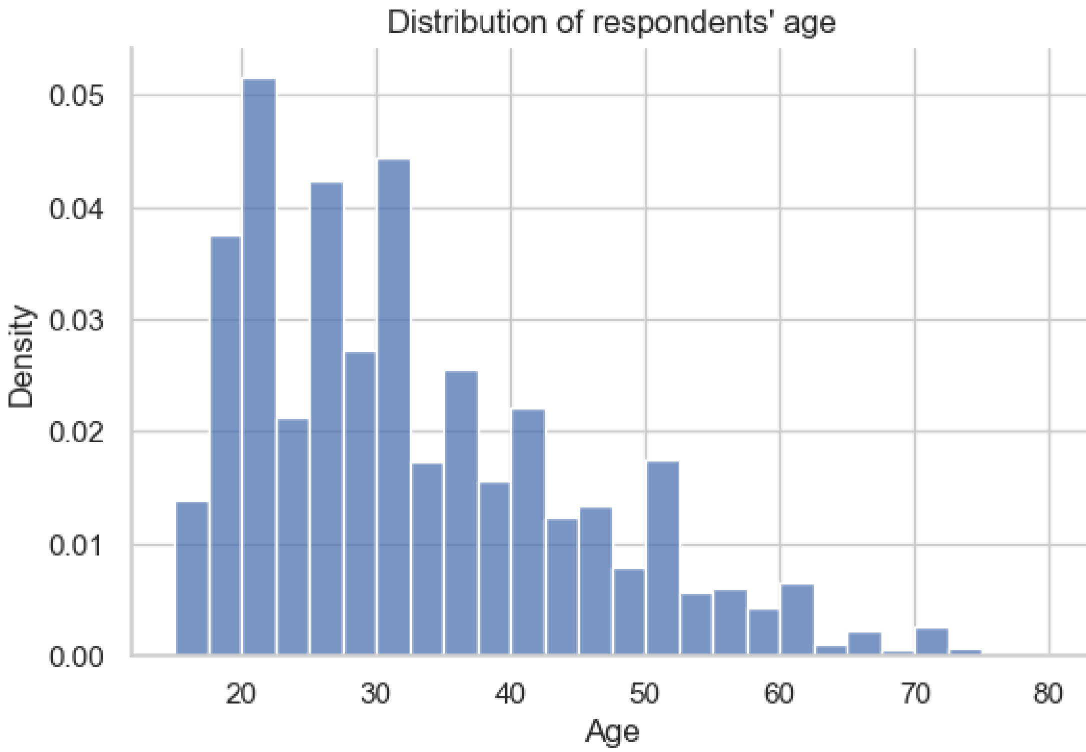
```
[ ]: <seaborn.axisgrid.FacetGrid at 0x225385fbc10>
```



Section A.2: Histogram

[ ]:
```
# Use a different seaborn theme
sns.set_theme(style="whitegrid")

sns.displot(
    data=afghan, x='age', stat='density', height=4, aspect=1.5
).set(title="Distribution of respondents' age", xlabel='Age')
```

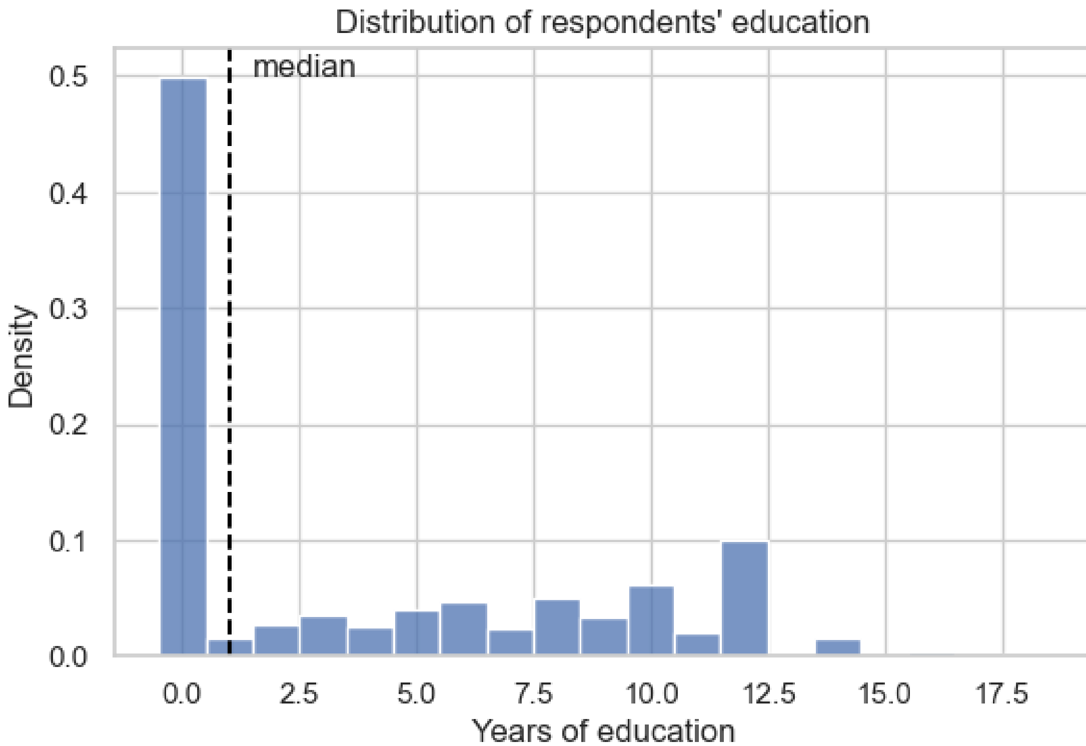
[ ]: <seaborn.axisgrid.FacetGrid at 0x225385fbb50>



By default, seaborn removes the top and right plot spines. We can use the `despine()` method to add them back.

[ ]:
```
# histogram of education
sns.displot(
    data=afghan, x='educ.years', stat='density',
    binrange=(-0.5, 18.5), binwidth=1, height=4, aspect=1.5
).set(title="Distribution of respondents' education",
      xlabel='Years of education').despine(right=False, top=False)

# add a vertical line representing the median
plt.axvline(x=afghan['educ.years'].median(), color='black', linestyle='--')

# add a text label for the median
plt.text(x=1.5, y=0.5, s='median')
```

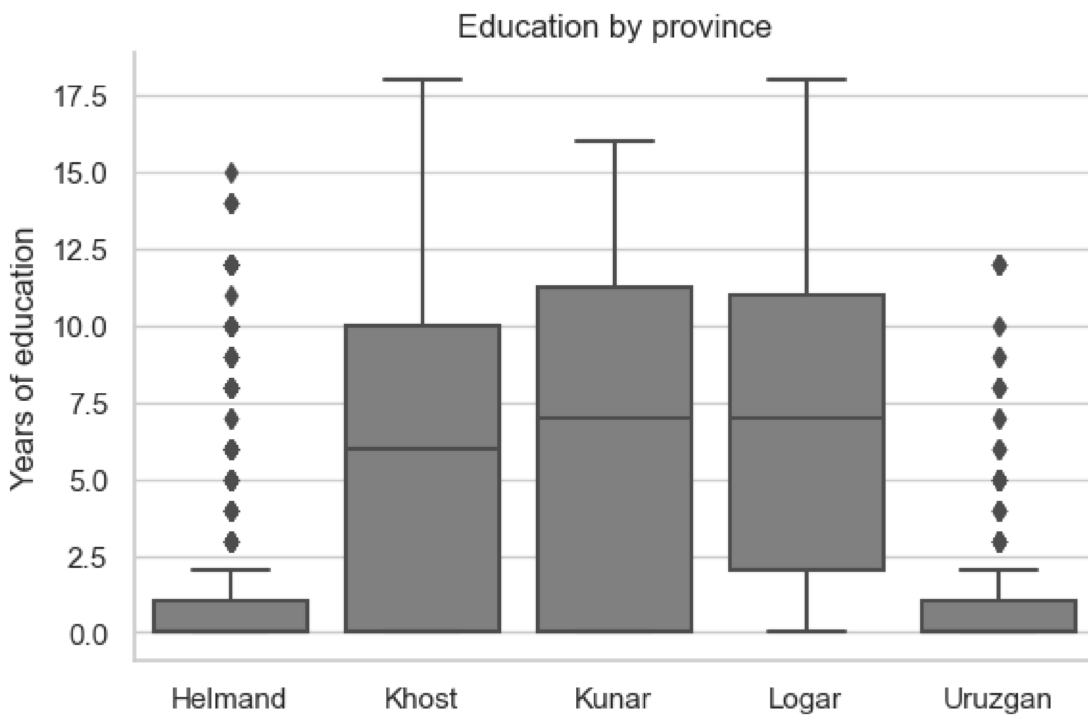
[ ]:
```
Text(1.5, 0.5, 'median')
```



Section A.3: Box Plots and Subplots

[ ]:
```
sns.catplot(
    data=afghan, x='province', y='educ.years', kind='box', color='gray',
    height=4, aspect=1.5
).set(title='Education by province', xlabel='', ylabel='Years of education')
```

[ ]:
```
<seaborn.axisgrid.FacetGrid at 0x225386c0ac0>
```



[ ]:
```
afghan_village.head()
```

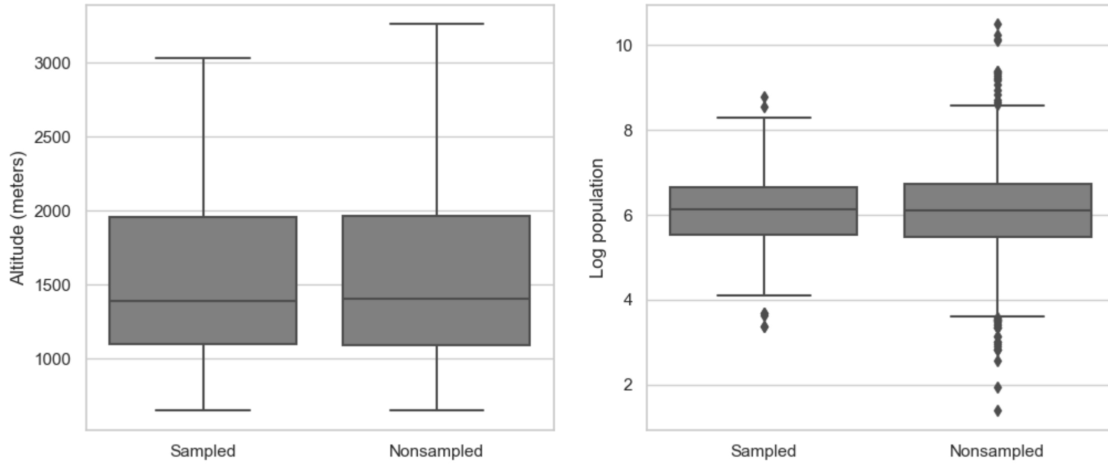
[ ]:

	altitude	population	village.surveyed	village_surveyed_desc	log_pop
0	1959.0800	197	1	Sampled	5.283204
1	2425.8799	744	0	Nonsampled	6.612041
2	2236.6001	179	1	Sampled	5.187386
3	1691.7600	225	0	Nonsampled	5.416100
4	1928.0400	379	0	Nonsampled	5.937536

Creating subplots requires using matplotlib subplots and seaborn axes-level plotting functions.

[ ]:
```
fig, axs = plt.subplots(1, 2, figsize=(12, 5))

# boxplots for altitude
sns.boxplot(
    data=afghan_village, x='village_surveyed_desc', y='altitude',
    color='gray', ax=axs[0]
).set(ylabel='Altitude (meters)', xlabel='')

# boxplots for log population
sns.boxplot(
    data=afghan_village, x='village_surveyed_desc', y='log_pop',
    color='gray', ax=axs[1]
).set(ylabel='Log population', xlabel='')
```

```
[ ]: [Text(0, 0.5, 'Log population'), Text(0.5, 0, '')]
```



Section A.4: Scatterplots and Facets

```
[ ]: congress.head()
```

```
[ ]:    congress  district    state     party          name  dwnom1  dwnom2
     0        80         0      USA  Democrat        TRUMAN  -0.276   0.016
     1        80         1  ALABAMA  Democrat     BOYKIN  F.  -0.026   0.796
     2        80         2  ALABAMA  Democrat      GRANT  G.  -0.042   0.999
     3        80         3  ALABAMA  Democrat    ANDREWS  G.  -0.008   1.005
     4        80         4  ALABAMA  Democrat      HOBBS  S.  -0.082   1.066
```

```
[ ]: # create a new column that formats congress as a string
     congress['Congress'] = congress['congress'].astype(str) + 'th'

     congress[['congress', 'Congress']].head()
```

```
[ ]:    congress Congress
     0        80     80th
     1        80     80th
     2        80     80th
     3        80     80th
     4        80     80th
```

```
[ ]: # recall, we stored some plotting parameters for re-use
     xlab
```

```
[ ]: 'Economic liberalism/conservatism'
```

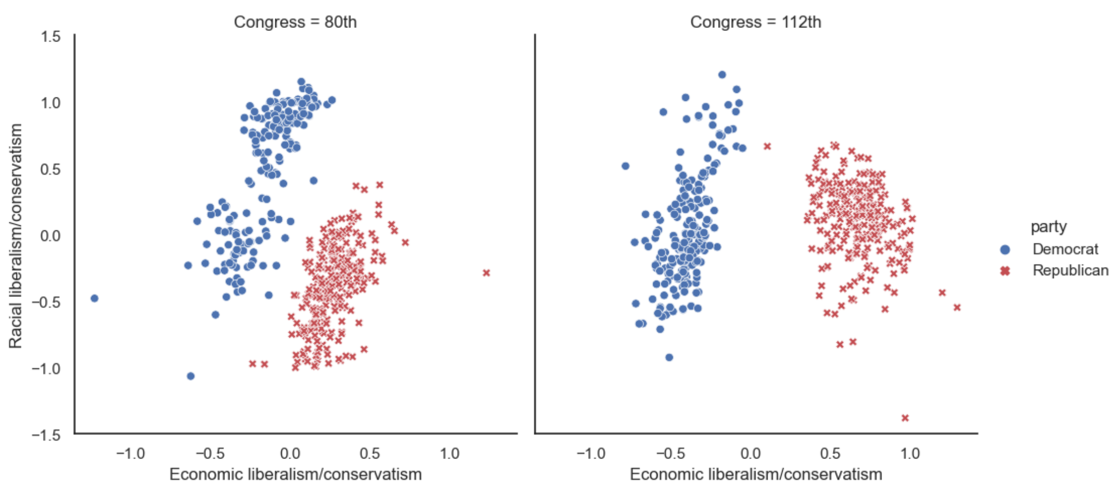
```
[ ]: lim
```

```
[ ]: (-1.5, 1.5)
```

We can specify a variable for facets using the `col` argument.

```
[ ]: sns.set_theme(style="white")

     # scatterplot: facets for 80th and 112th congresses
     sns.relplot(
         data=congress.loc[(congress['congress'].isin([80,112])) &
                           (congress['party'] != 'Other')],
         x='dwnom1', y='dwnom2', hue='party', style='party', palette=['b', 'r'],
         col='Congress' # specify the column for faceting
     ).set(xlabel=xlab, ylabel=ylab, ylim=lim)
```

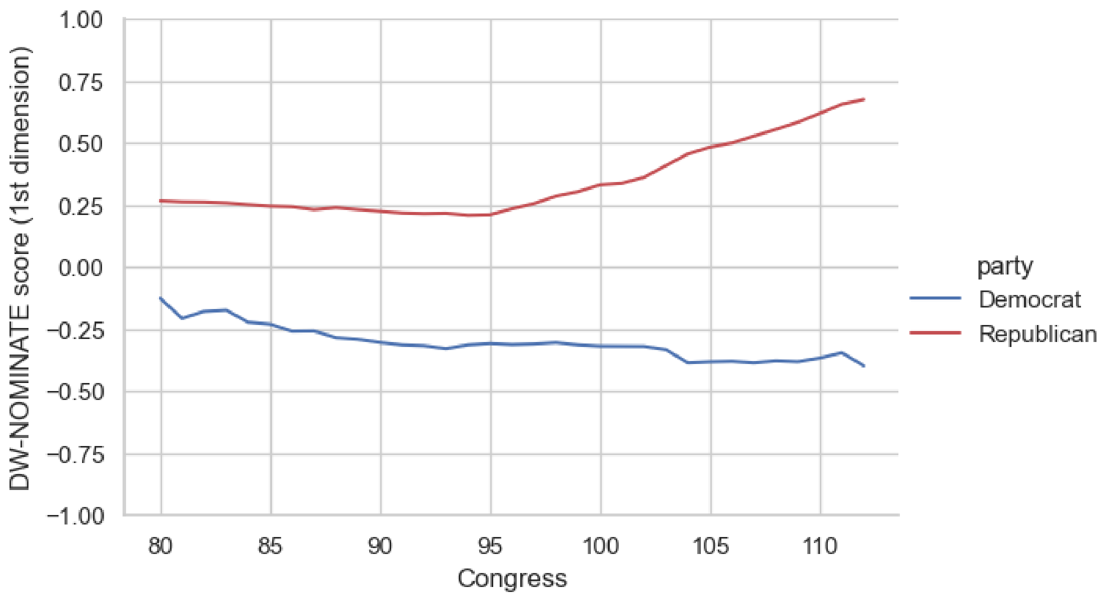
```
[ ]: <seaborn.axisgrid.FacetGrid at 0x22539beabc0>
```



Section A.5: Comparing Time Series

```
[ ]: sns.set_theme(style="whitegrid")

     sns.relplot(
         data=dwn1_med, x='congress', y='dwnom1', hue='party', kind='line',
         palette=['b', 'r'], height=4, aspect=1.5
     ).set(ylim=(-1, 1), xlabel='Congress',
           ylabel='DW-NOMINATE score (1st dimension)')
```

```
[ ]: <seaborn.axisgrid.FacetGrid at 0x225385fbf10>
```



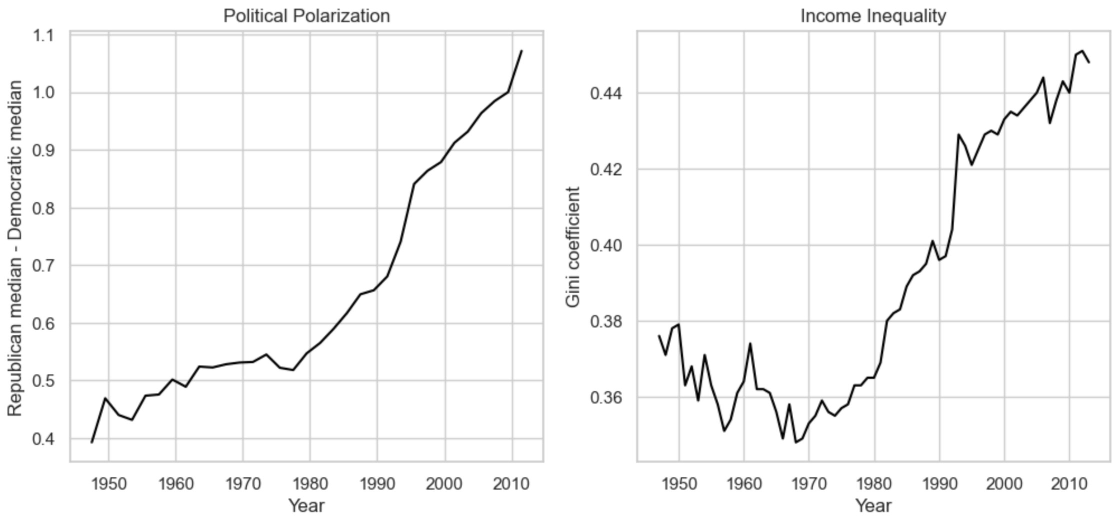

```
[ ]: # recall, we calculated median differences
     med_diff.head()
```

```
[ ]: 0    0.3925
     1    0.4690
     2    0.4400
     3    0.4315
     4    0.4735
     Name: dwnom1, dtype: float64
```

```
[ ]: # Plot political polarization and income inequality side-by-side
     fig, axs = plt.subplots(1, 2, figsize=(12, 5))

     # time series plot for partisan differences
     # notice, we can feed x and y directly
     sns.lineplot(
         x=np.arange(1947.5, 2012.5, step=2), y=med_diff, color='black', ax=axs[0]
     ).set(title='Political Polarization', xlabel='Year',
           ylabel='Republican median - Democratic median')

     # time-series plot for Gini coefficient
     sns.lineplot(
         data=gini, x='year', y='gini', color='black', ax=axs[1]
     ).set(title='Income Inequality', ylabel='Gini coefficient', xlabel='Year')
```

```
[ ]: [Text(0.5, 1.0, 'Income Inequality'),
      Text(0, 0.5, 'Gini coefficient'),
```

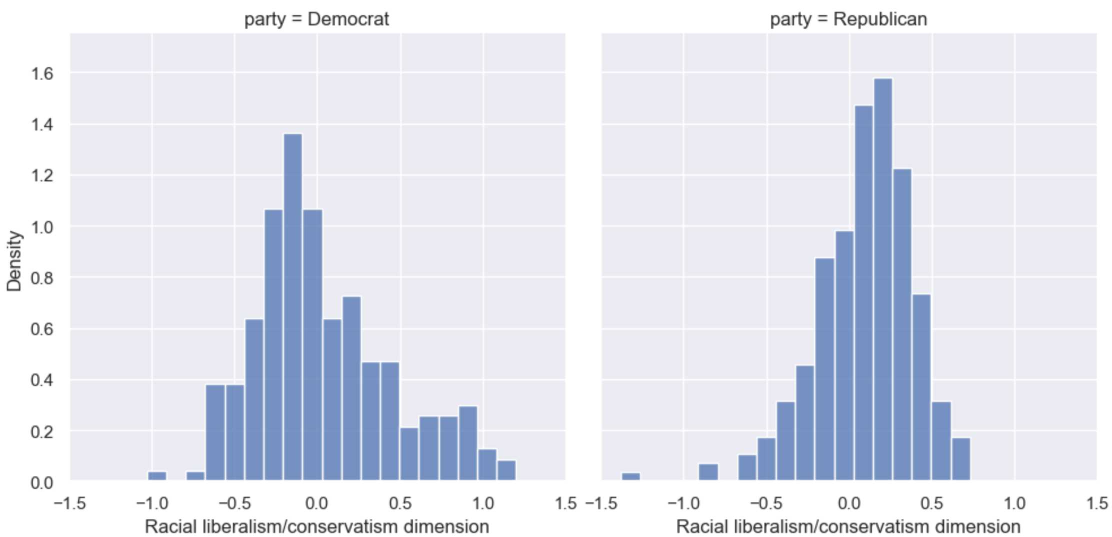
```
Text(0.5, 0, 'Year')]
```



Section A.6: Comparing Distributions

[ ]:
```
sns.set_theme(style="darkgrid")

# Facet: use common_norm=False to ensure density is calculated for each facet
sns.displot(
    data=congress.loc[(congress['congress'] == 112) &
                      (congress['party'] != 'Other')],
    x='dwnom2', col='party', stat='density', common_norm=False
).set(xlim=(-1.5, 1.5), ylim=(0, 1.75),
      xlabel='Racial liberalism/conservatism dimension')
```

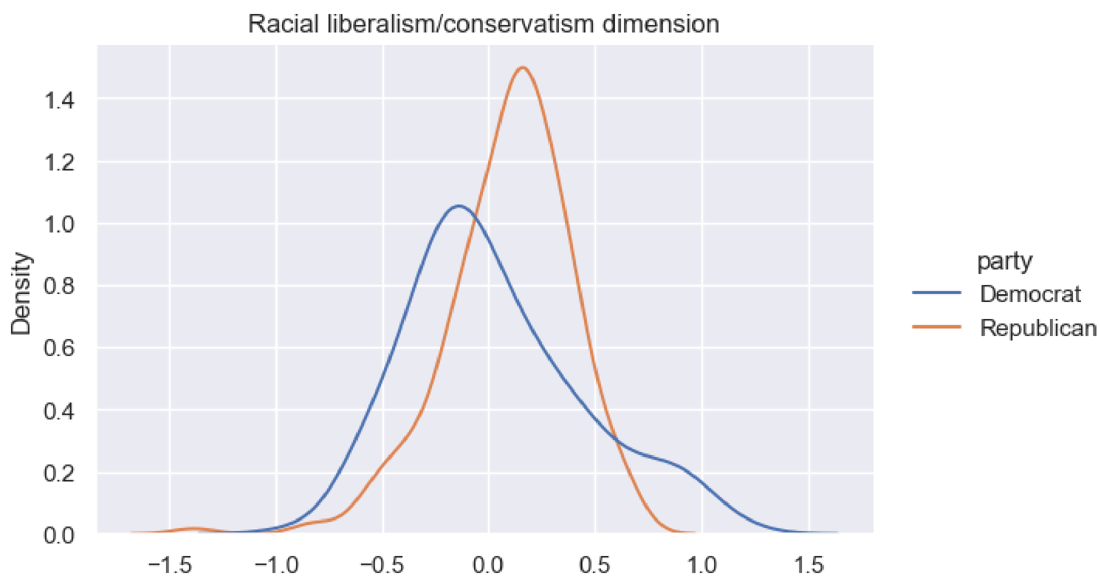
[ ]:
```
<seaborn.axisgrid.FacetGrid at 0x2253a43f8b0>
```



A kernel density estimation (KDE) plot is useful if we want to overlay distributions.

```
[ ]: # KDE
sns.displot(
    data=congress.loc[(congress['congress'] == 112) &
                      (congress['party'] != 'Other')],
    x='dwnom2', hue='party', kind='kde', common_norm=False,
    height=4, aspect=1.5
).set(title='Racial liberalism/conservatism dimension', xlabel='')
```

```
[ ]: <seaborn.axisgrid.FacetGrid at 0x2253ad53bb0>
```

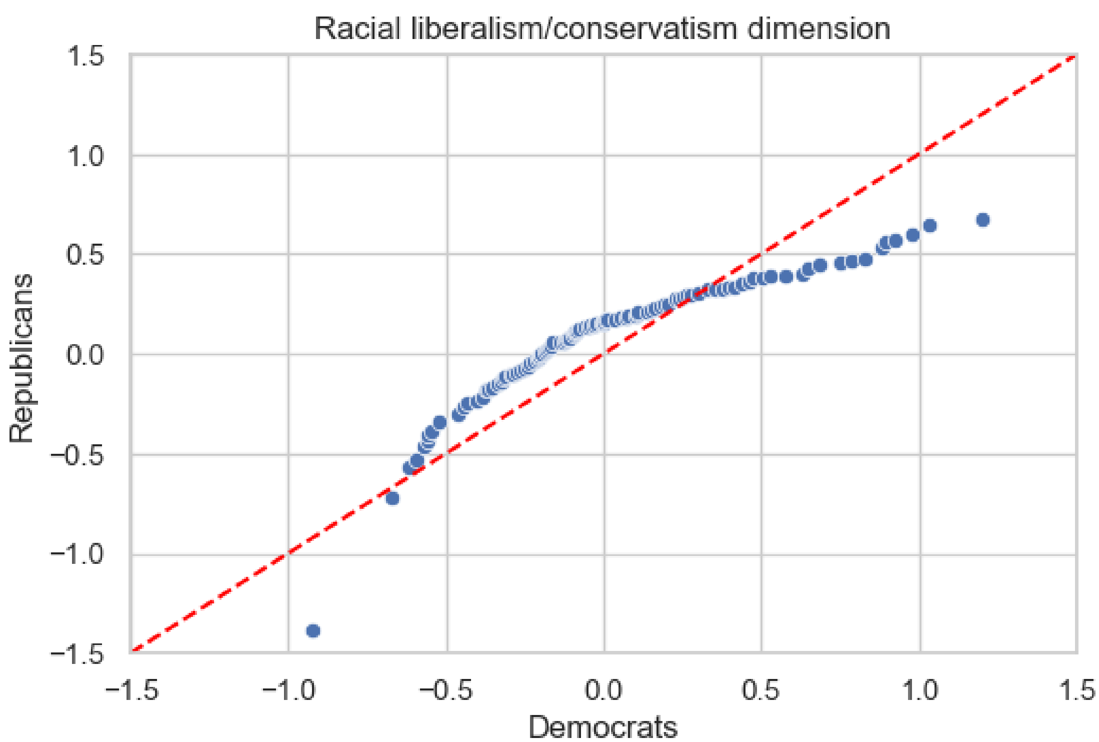


```
[ ]: # recall, we developed percentiles to build a Q-Q plot
demq.head()
```

```
[ ]: 0.00   -0.92500
0.01   -0.67241
0.02   -0.61904
0.03   -0.59336
0.04   -0.56652
Name: dwnom2, dtype: float64
```

```
[ ]: # Quantile-Quantile Plot
sns.set_theme(style="whitegrid")

sns.relplot(
    x = demq, y = repq, height=4, aspect=1.5
).set(xlabel='Democrats', ylabel='Republicans',
      title='Racial liberalism/conservatism dimension',
      ylim=(-1.5, 1.5), xlim=(-1.5, 1.5)).despine(
            right=False, top=False
      )

plt.gca().axline((0, 0), slope=1, color='red', linestyle='--')
```

```
[ ]: <matplotlib.lines._AxLine at 0x2253adb6980>
```



Section A.7: Comparing Clusters

[ ]:
```
# recall our plotting inputs for the cluster plots
dwnom80.head()
```

[ ]:

	dwnom1	dwnom2
0	-0.276	0.016
1	-0.026	0.796
2	-0.042	0.999
3	-0.008	1.005
4	-0.082	1.066

[ ]:
```
k80four_labels[:10]
```

[ ]:
```
array([0, 3, 3, 3, 3, 3, 3, 3, 3, 3])
```

[ ]:
```
k112four.cluster_centers_
```

[ ]:
```
array([[ 0.74096512, -0.21222093],
       [-0.43576812, -0.20002899],
       [ 0.64278205,  0.25755769],
       [-0.29379365,  0.54219048]])
```

[ ]:
```
# plot the clusters side-by-side
fig, axs = plt.subplots(1,2, figsize=(12, 5))

sns.scatterplot(
    data=dwnom80, x='dwnom1', y='dwnom2', hue=k80four_labels, legend=False,
    palette='pastel', ax=axs[0], # plot 1
    ).set(title='80th Congress', xlabel=xlab, ylabel=ylab, xlim=lim, ylim=lim)

sns.scatterplot(
    x=k80four.cluster_centers_[:,0], y=k80four.cluster_centers_[:,1],
    legend=False, color='black', s=100, marker='X', ax=axs[0], # plot 1
    )

sns.scatterplot(
    data=dwnom112, x='dwnom1', y='dwnom2', hue=k112four_labels, legend=False,
    palette='pastel', ax=axs[1], # plot 2
    ).set(title='112th Congress', xlabel=xlab, ylabel='', xlim=lim, ylim=lim)

sns.scatterplot(
    x=k112four.cluster_centers_[:,0], y=k112four.cluster_centers_[:,1],
    legend=False, color='black', s=100, marker='X', ax=axs[1], # plot 2
    )
```

[ ]: <Axes: title={'center': '112th Congress'}, xlabel='Economic liberalism/conservatism'>