Olga Tumurova Final Project Code

December 20, 2024

[1]:
```
!pip install ISLP -q
!pip install l0bnb linearmodels matplotlib seaborn scikit-learn xgboost␣
 ↪lightgbm -q
!pip install --upgrade econml -q
!pip install causalinference dowhy tabulate -q
```

```
ERROR: pip's dependency resolver does not currently take into account all
the packages that are installed. This behaviour is the source of the following
dependency conflicts.
numba 0.57.1 requires numpy<1.25,>=1.21, but you have numpy 1.26.4 which is
incompatible.
ERROR: pip's dependency resolver does not currently take into account
all the packages that are installed. This behaviour is the source of the
following dependency conflicts.
pygam 0.9.1 requires numpy>=1.25; python_version >= "3.9" and python_version <
"3.13", but you have numpy 1.24.4 which is incompatible.
ERROR: pip's dependency resolver does not currently take into account
all the packages that are installed. This behaviour is the source of the
following dependency conflicts.
linearmodels 6.1 requires Cython>=3.0.10, but you have cython 0.29.37 which is
incompatible.
```

[2]:
```
import dowhy
import networkx as nx
import numpy as np
import pandas as pd
import warnings
import matplotlib.pyplot as plt
import statsmodels.api as sm
```

```
import seaborn as sns
import scipy

from matplotlib.cm import get_cmap
from matplotlib.pyplot import subplots

from statsmodels.api import OLS

from sklearn.model_selection import train_test_split, cross_val_predict
import sklearn.model_selection as skm
import sklearn.linear_model as skl
from sklearn.metrics import mean_squared_error
from sklearn.preprocessing import StandardScaler
from sklearn.pipeline import Pipeline
from sklearn.linear_model import LinearRegression, LogisticRegression
from sklearn.neighbors import KNeighborsRegressor
from sklearn.tree import (
    DecisionTreeRegressor as DTR,
    plot_tree,
)
from sklearn.ensemble import RandomForestRegressor, GradientBoostingRegressor

from lightgbm import LGBMRegressor

from joblib import Parallel, delayed

from dowhy import CausalModel

from ISLP.models import ModelSpec as MS, Stepwise, sklearn_selected,␣
 ↪sklearn_selection_path
from l0bnb import fit_path

from tabulate import tabulate

from econml.grf import CausalForest
```

[3]:
```
#Cumulative gain plot functions from CIBT-21-Meta-Learners Notebook (ECO2425␣
 ↪Materials Week 8)
from toolz import curry
@curry
def elast(data, y, t):
    return (np.sum((data[t] - data[t].mean())*(data[y] - data[y].mean())) /
            np.sum((data[t] - data[t].mean())**2))


def cumulative_gain(dataset, prediction, y, t, min_periods=30, steps=100):
    size = dataset.shape[0]
```

```
    ordered_df = dataset.sort_values(prediction, ascending=False).
↪reset_index(drop=True)
    n_rows = list(range(min_periods, size, size // steps)) + [size]
    return np.array([elast(ordered_df.head(rows), y, t) * (rows/size) for rows␣
↪in n_rows])
```

[4]:
```
np.random.seed(88)
random_st = 55
```

[5]:
```
control_names = {
    'avg_cloud_coverage': 'Average Cloud Coverage',
    'avg_rainfall_millimeter': 'Average Rainfall (mm)',
    'avg_temperature': 'Average Temperature',
    'BBC_SNR_Ratio': 'BBC SNR Ratio',
    'popul_000s': 'Population',
    'female_share': '% Female',
    'illit_share': '% Illiterate'
}

graph_names_1921 = {**{
    'share_socialist1921': 'Socialist Share (1921)',
    'share_republican1921': 'Republican Share (1921)',
    'share_catholic1921': 'Christian Share (1921)',
    'share_communist1921': 'Communist Share (1921)',
    'share_independent1921': 'Independent Share (1921)',
    'share_altri1921': 'Other Parties Share (1921)',
    'aggregated_share1921': 'Right-Wing Share (1921)',
},  **control_names}


parties_1921 = ['share_republican1921', 'share_socialist1921',
                'share_catholic1921', 'share_communist1921',
                'share_independent1921', 'share_altri1921']
```

Data Prep

[6]:
```
main_data = pd.read_stata("OG Full Dataset.dta")
restricted = main_data[(main_data['date']<=29) & (main_data['date']>=10) &
                       (main_data['gustav']>=1) & (main_data['dist_lib']>=-1) &
                        (main_data['dist_lib']<=10)]
```

[7]:
```
restricted = restricted.rename(columns = {"vict_rappr_aggr_AT_ep":␣
↪"violence_episode_total",
                                                                  ␣
↪"vict_rappr_aggr_civ_AT_ep": "violence_episode_civilian_resistance",
                                                                  ␣
↪"vict_rappr_aggr_part_AT_ep": "violence_episode_partisan_resistance" })
```

```
restricted = restricted.rename(columns = {"MW_SNR": "BBC_SNR_Ratio",
                                          "rain": "avg_rainfall_millimeter",
                                          "cloud": "avg_cloud_coverage",
                                          "temp": "avg_temperature",
                                          "popres_1951_tot": "popul_000s",
                                          "female_share_1951": "female_share",
                                          "analfshare_1951_tot": "illit_share"})

restricted.rename(columns=lambda x: x.replace('p_voti2_liberali',␣
 ↪'share_liberal') if 'p_voti2_liberali' in x else x, inplace=True)
restricted.rename(columns=lambda x: x.replace('p_voti2_socialisti',␣
 ↪'share_socialist') if 'p_voti2_socialisti' in x else x, inplace=True)
restricted.rename(columns=lambda x: x.replace('p_voti2_cattolici',␣
 ↪'share_catholic') if 'p_voti2_cattolici' in x else x, inplace=True)
restricted.rename(columns=lambda x: x.replace('p_voti2_comunisti',␣
 ↪'share_communist') if 'p_voti2_comunisti' in x else x, inplace=True)
restricted.rename(columns=lambda x: x.replace('p_voti2_fascisti',␣
 ↪'share_fascist') if 'p_voti2_fascisti' in x else x, inplace=True)
restricted.rename(columns=lambda x: x.replace('p_voti2_destra',␣
 ↪'share_conservative') if 'p_voti2_destra' in x else x, inplace=True)
restricted.rename(columns=lambda x: x.replace('p_voti2_autonomisti',␣
 ↪'share_independent') if 'p_voti2_autonomisti' in x else x, inplace=True)
restricted.rename(columns=lambda x: x.replace('p_voti2_altri', 'share_altri')␣
 ↪if 'p_voti2_altri' in x else x, inplace=True)
restricted.rename(columns=lambda x: x.replace('p_voti2_radicali',␣
 ↪'share_radical') if 'p_voti2_radicali' in x else x, inplace=True)
restricted.rename(columns=lambda x: x.replace('p_voti2_repubblicani',␣
 ↪'share_republican') if 'p_voti2_repubblicani' in x else x, inplace=True)

restricted = restricted.loc[:, restricted.columns.str.contains('|'.
 ↪join(['dist_lib', '1924', '1921', '1919', 'avg_cloud_coverage',␣
 ↪'avg_rainfall_millimeter',
                                                                 ␣
 ↪'avg_temperature', 'BBC_SNR_Ratio', 'cod_istat103',
                                                                 ␣
 ↪'violence_episode', 'popul_000s', 'female_share', 'illit_share']))]
restricted = restricted.loc[:, ~restricted.columns.str.
 ↪contains('_miss|_l01|_lgt1|dist_lib_abs')]

print(restricted.columns.tolist())
```

```
['cod_istat103', 'dist_lib', 'violence_episode_total',
'violence_episode_civilian_resistance', 'violence_episode_partisan_resistance',
'BBC_SNR_Ratio', 'avg_rainfall_millimeter', 'avg_cloud_coverage',
'avg_temperature', 'illit_share', 'female_share', 'popul_000s',
```

```
'share_liberal1919', 'share_conservative1919', 'share_catholic1919',
'share_socialist1919', 'share_radical1919', 'share_republican1919',
'share_fascist1919', 'share_communist1919', 'share_independent1919',
'share_altri1919', 'share_liberal1921', 'share_conservative1921',
'share_catholic1921', 'share_socialist1921', 'share_radical1921',
'share_republican1921', 'share_fascist1921', 'share_communist1921',
'share_independent1921', 'share_altri1921', 'share_liberal1924',
'share_conservative1924', 'share_catholic1924', 'share_socialist1924',
'share_radical1924', 'share_republican1924', 'share_fascist1924',
'share_communist1924', 'share_independent1924', 'share_altri1924']
```

[8]:
```
print("N:", len(restricted))
assert np.isinf(restricted).any(axis=1).sum() == 0
print("N with NAs:", restricted.isna().any(axis=1).sum())

restricted_na = restricted[restricted.isna().any(axis=1)].isna().sum()
print(restricted_na)

#156 obs of 66k are missing elections data - less than 0.25%, can drop from␣
 ↪analysis
main_analysis = restricted.dropna()
print("N (clean):", len(main_analysis))
```

```
N: 66297
N with NAs: 156
cod_istat103                            0
dist_lib                                0
violence_episode_total                  0
violence_episode_civilian_resistance    0
violence_episode_partisan_resistance    0
BBC_SNR_Ratio                           0
avg_rainfall_millimeter                 0
avg_cloud_coverage                      0
avg_temperature                         0
illit_share                             0
female_share                            0
popul_000s                              0
share_liberal1919                     156
share_conservative1919                156
share_catholic1919                    156
share_socialist1919                   156
share_radical1919                     156
share_republican1919                  156
share_fascist1919                     156
share_communist1919                   156
share_independent1919                 156
share_altri1919                       156
share_liberal1921                     156
```

```
share_conservative1921          156
share_catholic1921              156
share_socialist1921             156
share_radical1921               156
share_republican1921            156
share_fascist1921               156
share_communist1921             156
share_independent1921           156
share_altri1921                 156
share_liberal1924               156
share_conservative1924          156
share_catholic1924              156
share_socialist1924             156
share_radical1924               156
share_republican1924            156
share_fascist1924               156
share_communist1924             156
share_independent1924           156
share_altri1924                 156
dtype: int64
N (clean): 66141
```

II. Data Summary

[9]:
```
reg_data = main_analysis.copy()
reg_data['aggregated_share1919'] = reg_data['share_liberal1919'] +␣
 ↪reg_data['share_conservative1919'] + reg_data['share_radical1919']
reg_data['aggregated_share1921'] = reg_data['share_liberal1921'] +␣
 ↪reg_data['share_conservative1921'] + reg_data['share_fascist1921'] +␣
 ↪reg_data['share_radical1921']
reg_data['aggregated_share1924'] = reg_data['share_liberal1924'] +␣
 ↪reg_data['share_conservative1924'] + reg_data['share_fascist1924'] +␣
 ↪reg_data['share_radical1924']
reg_data = reg_data.loc[:, ~reg_data.columns.str.contains('|'.
 ↪join(['share_liberal', 'share_conservative', 'share_fascist',␣
 ↪'share_radical']))]
reg_data = reg_data.drop(['share_communist1919', 'share_independent1919',␣
 ↪'share_altri1919', 'share_altri1924'], axis=1)
```

[10]:
```
y = reg_data['violence_episode_total']

y_stat = pd.DataFrame({
    'Mean': [y.mean()],
    'Median': [y.median()],
    'Standard Deviation': [y.std()],
    'Range': [y.max() - y.min()]
})
```

```
print(y_stat)
```

```
      Mean  Median  Standard Deviation  Range
0  0.05269     0.0            0.348772     17
```

[11]:
```
expl = reg_data.loc[:, reg_data.columns.str.contains('|'.join(['share_',␣
 ↪'aggregated_share']))]

pd.DataFrame({
        'Mean': expl.mean(),
        'Median': expl.median(),
        'Standard Deviation': expl.std(),
        'Range': expl.max() - expl.min()
    })
```

[11]:

	Mean	Median	Standard Deviation	Range
share_catholic1919	0.312680	0.257426	0.209821	1.075244
share_socialist1919	0.258327	0.200388	0.260045	1.000000
share_republican1919	0.006111	0.000000	0.038638	0.678832
share_catholic1921	0.298785	0.259740	0.195706	1.000000
share_socialist1921	0.227981	0.182595	0.226788	1.000000
share_republican1921	0.008165	0.000000	0.040436	0.621589
share_communist1921	0.031051	0.000000	0.069989	0.857576
share_independent1921	0.000155	0.000000	0.003224	0.186633
share_altri1921	0.000206	0.000000	0.003171	0.113636
share_catholic1924	0.149738	0.103964	0.147932	1.000000
share_socialist1924	0.098932	0.043127	0.132400	0.822943
share_republican1924	0.013208	0.000000	0.046205	0.739130
share_communist1924	0.022001	0.007412	0.040581	0.720698
share_independent1924	0.018741	0.000000	0.120819	0.990338
aggregated_share1919	0.220703	0.165347	0.230946	1.000000
aggregated_share1921	0.227401	0.188406	0.231118	1.000000
aggregated_share1924	0.355661	0.331169	0.337808	1.000000

[12]:
```
controls_sum = reg_data.loc[:, ~reg_data.columns.str.contains('|'.
 ↪join(['dist_lib', 'cod_istat103','share_', 'aggregated_share', 'violence']))]

pd.DataFrame({
        'Mean': controls_sum.mean(),
        'Median': controls_sum.median(),
        'Standard Deviation': controls_sum.std(),
        'Range': controls_sum.max() - controls_sum.min()
    })
```

[12]:

	Mean	Median	Standard Deviation	Range
BBC_SNR_Ratio	59.387550	59.500000	5.403883	29.000000
avg_rainfall_millimeter	71.861458	55.400002	64.012100	382.500000

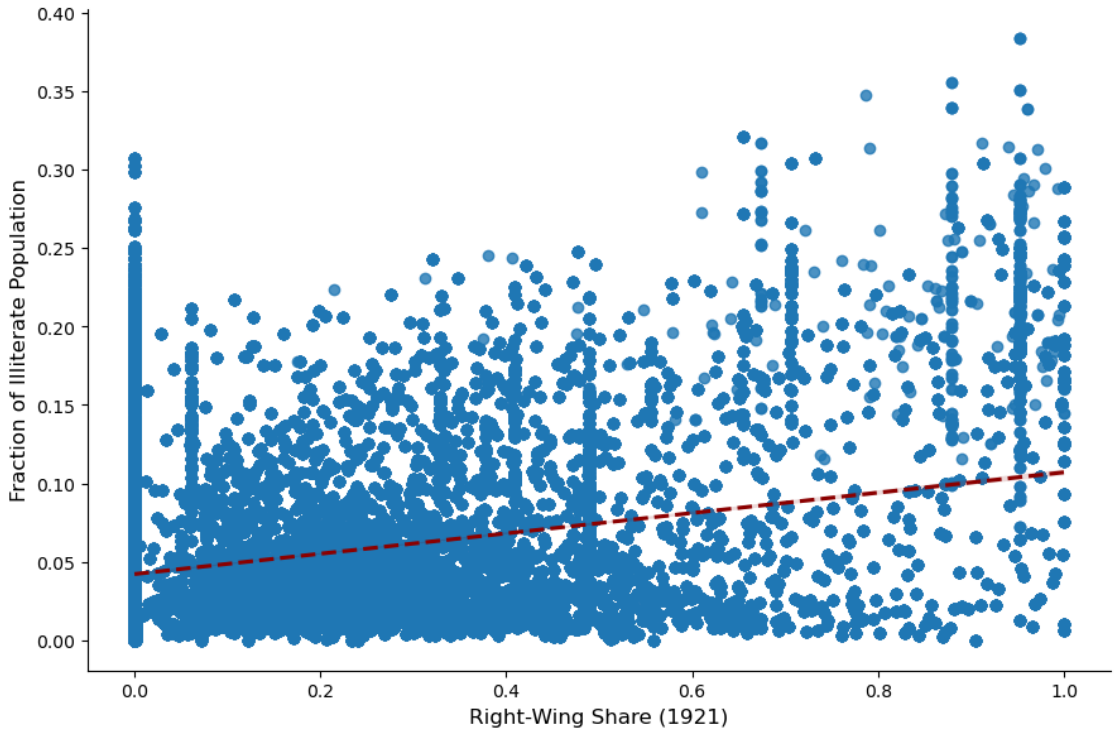
avg_cloud_coverage	57.239983	58.700001	8.742622	46.200001
avg_temperature	11.671016	11.700000	8.076022	39.100000
illit_share	0.057002	0.036347	0.055485	0.574884
female_share	0.503025	0.502339	0.019318	0.261095
popul_000s	5.540282	2.465000	32.188262	1651.679000

[13]:
```
corrheat_1921 = reg_data[['aggregated_share1921', 'share_catholic1921',␣
 ↪'share_socialist1921',
                          'share_republican1921', 'share_communist1921',␣
 ↪'share_independent1921',
                          'share_altri1921', 'violence_episode_total']]

corrheat_1921 = corrheat_1921.rename(columns={**graph_names_1921, ␣
 ↪**{'violence_episode_total': 'Violence Episodes'}})
corrheat_1921 = corrheat_1921.corr()

plt.figure(figsize=(10, 8))
corr_plot = sns.heatmap(corrheat_1921, annot=True, cmap='Blues', fmt=".2f",␣
 ↪linewidths=0.5)

corr_plot.get_xticklabels()[0].set_color('#bd2929')
corr_plot.get_yticklabels()[0].set_color('#bd2929')

corr_plot.get_xticklabels()[-1].set_color('#293fbd')
corr_plot.get_yticklabels()[-1].set_color('#293fbd')

corr_plot.get_xticklabels()[0].set_fontweight('bold')
corr_plot.get_yticklabels()[0].set_fontweight('bold')

corr_plot.get_xticklabels()[-1].set_fontweight('bold')
corr_plot.get_yticklabels()[-1].set_fontweight('bold')

rw = corrheat_1921.columns.get_loc('Right-Wing Share (1921)')
vi = corrheat_1921.columns.get_loc('Violence Episodes')

bl = plt.Rectangle((0, len(corrheat_1921) - 1), 1, 1, fill=False,␣
 ↪edgecolor='red', lw = 3)
tr = plt.Rectangle((len(corrheat_1921) - 1, 0), 1, 1, fill=False,␣
 ↪edgecolor='red', lw = 3)
corr_plot.add_patch(bl)
corr_plot.add_patch(tr)
```

[13]: <matplotlib.patches.Rectangle at 0x7fabb1235dd0>

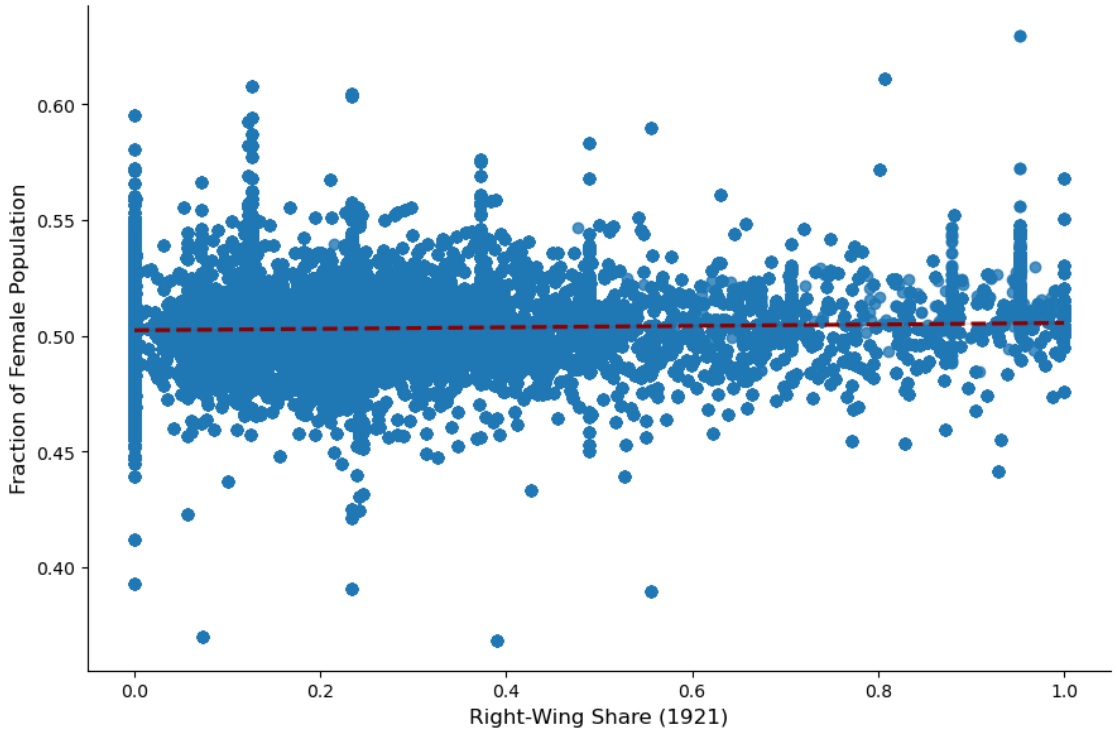
[14]:
```
filt_illit = reg_data[reg_data['illit_share'] < 0.5]
sns.lmplot(x='aggregated_share1921', y='illit_share', data=filt_illit, aspect=1.
 ↪5, height=6,
           line_kws={'color': 'darkred', 'linestyle': '--'})

plt.xlabel('Right-Wing Share (1921)', fontsize=12)
plt.ylabel('Fraction of Illiterate Population', fontsize=12)
```

[14]: Text(20.265625000000007, 0.5, 'Fraction of Illiterate Population')



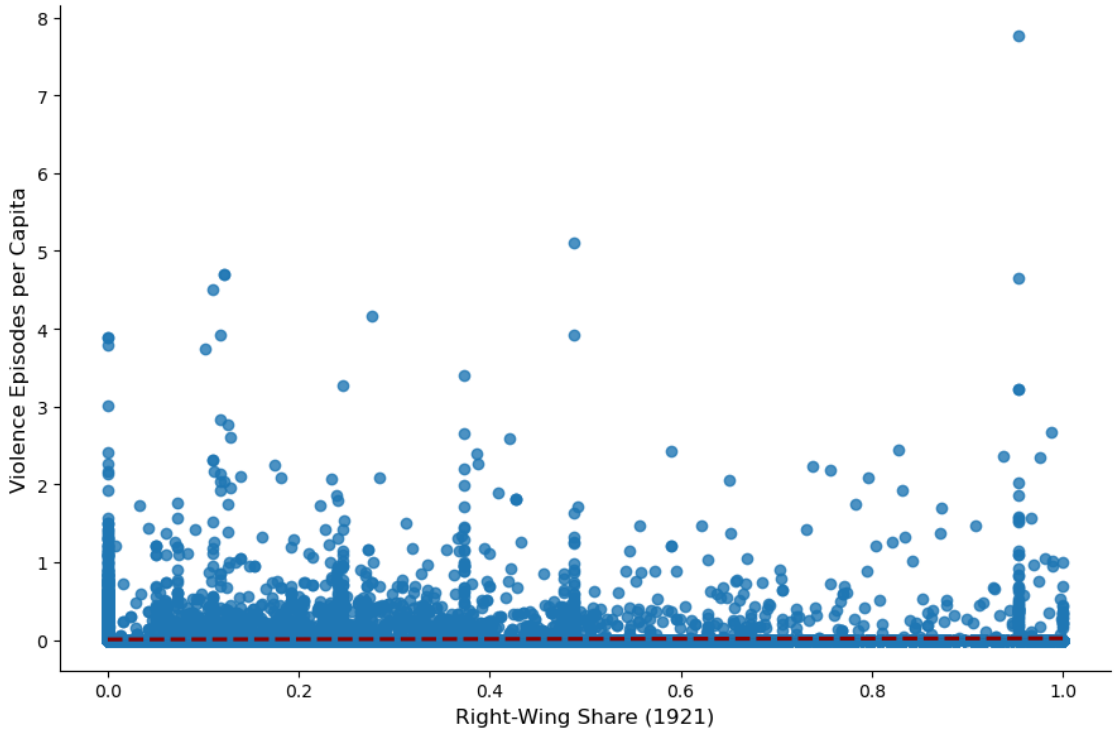
[15]:
```
sns.lmplot(x='aggregated_share1921', y='female_share', data=reg_data, aspect=1.
↪5, height=6,
           line_kws={'color': 'darkred', 'linestyle': '--'})

plt.xlabel('Right-Wing Share (1921)', fontsize=12)
plt.ylabel('Fraction of Female Population', fontsize=12)
```

[15]:
```
Text(20.265625000000007, 0.5, 'Fraction of Female Population')
```



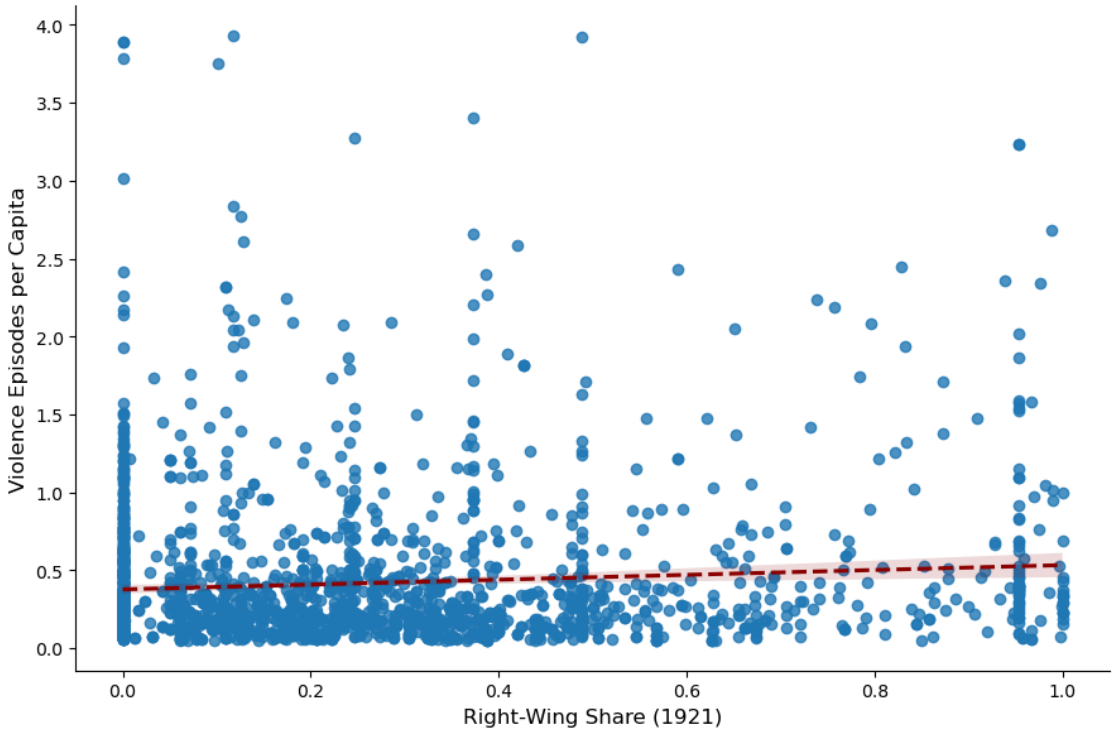
[16]:
```
scatter_data = reg_data.copy()
scatter_data['violence_per_capita'] = scatter_data['violence_episode_total'] /␣
 ↪scatter_data['popul_000s']
sns.lmplot(x='aggregated_share1921', y='violence_per_capita',␣
 ↪data=scatter_data, aspect=1.5, height=6,
           line_kws={'color': 'darkred', 'linestyle': '--'})

plt.xlabel('Right-Wing Share (1921)', fontsize=12)
plt.ylabel('Violence Episodes per Capita', fontsize=12)
```

[16]:
```
Text(42.39062500000001, 0.5, 'Violence Episodes per Capita')
```



[17]:
```
filt = scatter_data[(scatter_data['violence_per_capita'] > 0.05) &␣
 ↪(scatter_data['violence_per_capita'] < 4)]
sns.lmplot(x='aggregated_share1921', y='violence_per_capita', data=filt,␣
 ↪aspect=1.5, height=6,
           line_kws={'color': 'darkred', 'linestyle': '--'})

plt.xlabel('Right-Wing Share (1921)', fontsize=12)
plt.ylabel('Violence Episodes per Capita', fontsize=12)
```

[17]:
```
Text(29.140625000000007, 0.5, 'Violence Episodes per Capita')
```



III. Models

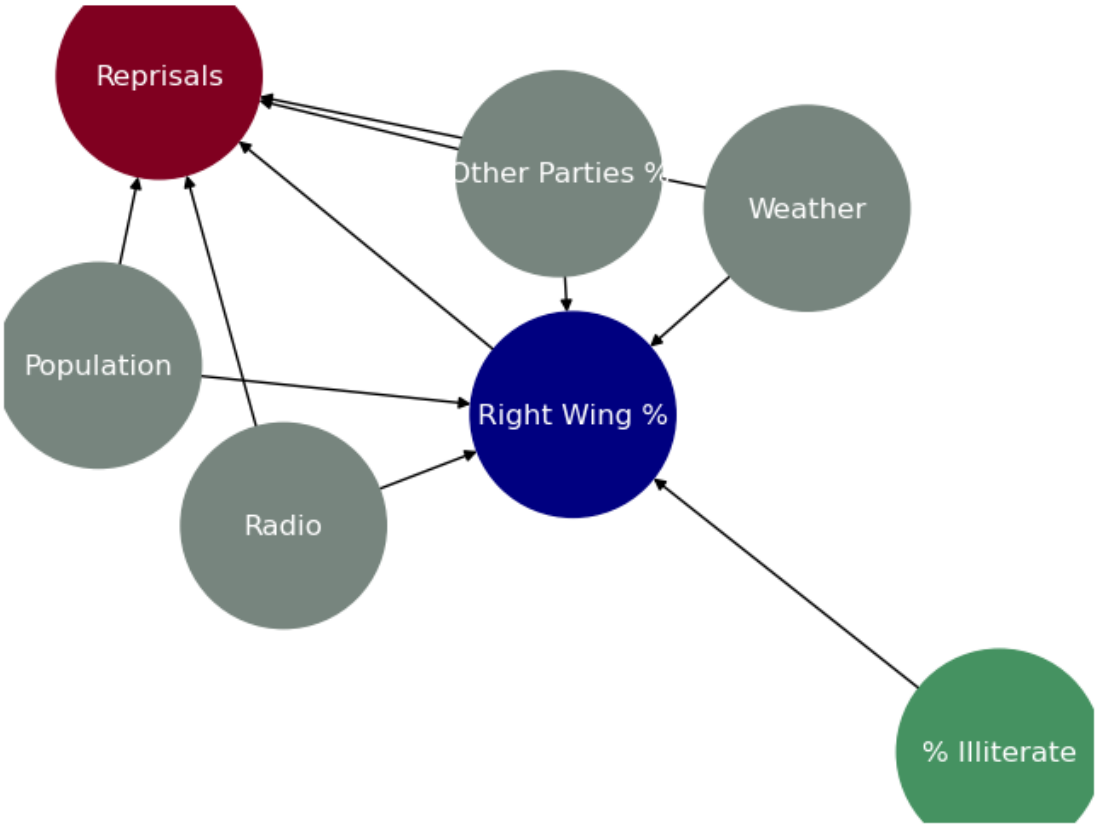
[Model 8] Directed Acyclic Graphs (DAGs)

[18]:
```
iv_gml = """graph [
directed 1
node [
    id 3
    label "Right Wing %"
]
node [
    id 1
    label "Reprisals"
]
node [
    id 2
    label "Weather"
]
node [
    id 0
    label "Radio"
]
node [
    id 4
```

```
    label "Population"
]

node [
    id 5
    label "% Illiterate"
]
node [
    id 6
    label "Other Parties %"
]
edge [
    source 0
    target 1
]
edge [
    source 5
    target 3
]
edge [
    source 4
    target 1
    ]
edge [
    source 4
    target 3
]
edge [
    source 2
    target 1
]

edge [
    source 3
    target 1
]
edge [
    source 0
    target 3
]
edge [
    source 2
    target 3
]
edge [
    source 6
    target 1
```

```
    ]
edge [
    source 6
    target 3
]
]
"""
```

[19]:
```
iv = nx.parse_gml(iv_gml)
nx.draw(G=iv, with_labels=True, node_size=7500,  node_color= ['#000080',␣
 ↪'#800020', '#77857E', '#77857E' , '#77857E', '#459261',  '#77857E'], ␣
 ↪font_color='white')
```

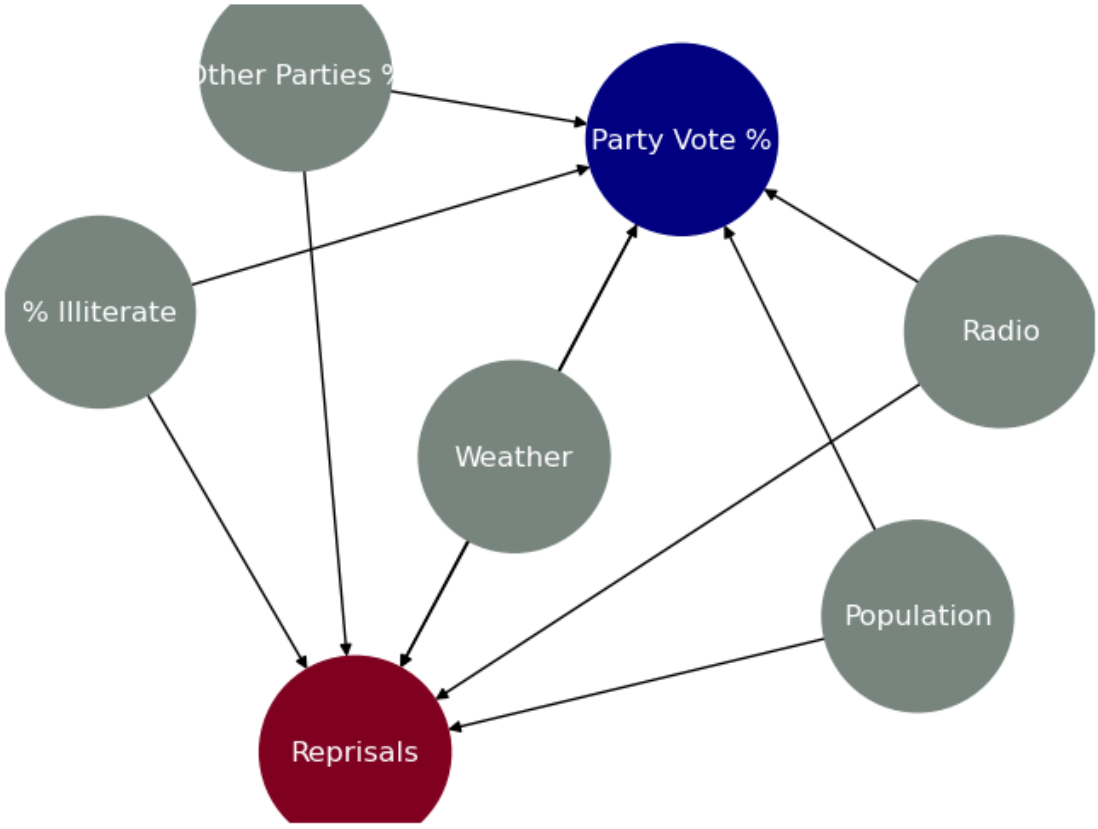


[20]:
```
non_iv_gml = """graph [
directed 1
node [
    id 3
    label "Party Vote %"
]
node [
```

```
    id 1
    label "Reprisals"
]
node [
    id 2
    label "Weather"
]
node [
    id 0
    label "Radio"
]
node [
    id 4
    label "Population"
]

node [
    id 5
    label "% Illiterate"
]
node [
    id 6
    label "Other Parties %"
]
edge [
    source 0
    target 1
]
edge [
    source 5
    target 3
]
edge [
    source 5
    target 1
]
edge [
    source 4
    target 1
    ]
edge [
    source 4
    target 3
]
edge [
    source 2
    target 1
```

```
]

edge [
    source 3
    target 1
]
edge [
    source 0
    target 3
]
edge [
    source 2
    target 3
]
edge [
    source 6
    target 3
]
edge [
    source 6
    target 1
]
]
"""
```

[21]:
```
non_iv = nx.parse_gml(non_iv_gml)
nx.draw(G=non_iv, with_labels=True, node_size=6500,  node_color= ['#000080',␣
 ↪'#800020', '#77857E', '#77857E' , '#77857E', '#77857E', '#77857E'], ␣
 ↪font_color='white')
```



[Models 1 & 2] OLS & IV Regressions

[22]:
```
controls = ['avg_cloud_coverage', 'avg_rainfall_millimeter', 'avg_temperature',␣
↪'BBC_SNR_Ratio', 'popul_000s', 'female_share', 'illit_share']
```

[23]:
```
controls_1921 = ['1921'] + controls
x = reg_data.loc[:, reg_data.columns.str.contains('|'.join(controls_1921))]
y = reg_data['violence_episode_total']
x = sm.add_constant(x)
ols_1921 = sm.OLS(y, x).fit()
print(ols_1921.summary())
```

```
                            OLS Regression Results
==============================================================================
==
Dep. Variable:     violence_episode_total   R-squared:
0.051
Model:                                OLS   Adj. R-squared:
0.051
Method:                     Least Squares   F-statistic:
252.9
```

```
Date:                    Fri, 20 Dec 2024   Prob (F-statistic):
0.00
Time:                           06:26:11   Log-Likelihood:
-22456.
No. Observations:                66141   AIC:
4.494e+04
Df Residuals:                    66126   BIC:
4.508e+04
Df Model:                           14
Covariance Type:            nonrobust
==============================================================================
===========
                              coef    std err          t      P>|t|      [0.025
0.975]
------------------------------------------------------------------------------
-----------
const                         0.1328      0.048      2.749      0.006       0.038
0.227
BBC_SNR_Ratio                -0.0027      0.000     -6.221      0.000      -0.004
-0.002
avg_rainfall_millimeter  2.351e-05    2.2e-05      1.070      0.285   -1.96e-05
6.66e-05
avg_cloud_coverage           -0.0029      0.000    -12.241      0.000      -0.003
-0.002
avg_temperature              -0.0019      0.000     -6.057      0.000      -0.003
-0.001
illit_share                   0.3617      0.033     11.059      0.000       0.298
0.426
female_share                  0.4567      0.070      6.501      0.000       0.319
0.594
popul_000s                    0.0020   4.14e-05     49.152      0.000       0.002
0.002
share_catholic1921            0.0027      0.008      0.352      0.725      -0.012
0.018
share_socialist1921           0.0102      0.007      1.461      0.144      -0.003
0.024
share_republican1921          0.3819      0.034     11.318      0.000       0.316
0.448
share_communist1921           0.0115      0.021      0.543      0.587      -0.030
0.053
share_independent1921        -0.1788      0.412     -0.434      0.664      -0.987
0.629
share_altri1921              -1.4251      0.419     -3.399      0.001      -2.247
-0.603
aggregated_share1921          0.0069      0.006      1.117      0.264      -0.005
0.019
==============================================================================
Omnibus:                   123988.306   Durbin-Watson:                   1.846
```

```
Prob(Omnibus):                  0.000   Jarque-Bera (JB):        378725496.750
Skew:                          14.111   Prob(JB):                         0.00
Kurtosis:                     372.633   Cond. No.                     3.79e+04
==============================================================================

Notes:
[1] Standard Errors assume that the covariance matrix of the errors is correctly
specified.
[2] The condition number is large, 3.79e+04. This might indicate that there are
strong multicollinearity or other numerical problems.
```

[24]:
```
controls_1921_iv = reg_data.loc[:, reg_data.columns.str.contains('|'.
 ↪join(controls_1921))].drop(columns='aggregated_share1921')

first_stage = sm.OLS(reg_data['aggregated_share1921'],
                     sm.add_constant(controls_1921_iv)).fit()

print(first_stage.summary())

first_stage_fitted = first_stage.fittedvalues

second_stage = sm.OLS(reg_data['violence_episode_total'],
                      sm.add_constant(controls_1921_iv.
 ↪assign(illit_share_hat=first_stage_fitted))).fit()

print(second_stage.summary())
```

```
                            OLS Regression Results
==============================================================================
Dep. Variable:     aggregated_share1921   R-squared:                       0.149
Model:                              OLS   Adj. R-squared:                  0.149
Method:                   Least Squares   F-statistic:                     892.6
Date:                  Fri, 20 Dec 2024   Prob (F-statistic):               0.00
Time:                          06:26:24   Log-Likelihood:                8385.2
No. Observations:                66141   AIC:                         -1.674e+04
Df Residuals:                    66127   BIC:                         -1.661e+04
Df Model:                           13
Covariance Type:              nonrobust
==============================================================================
===========
                             coef    std err          t      P>|t|      [0.025
0.975]
------------------------------------------------------------------------------
-----------
const                        0.1450      0.030      4.788      0.000       0.086
0.204
BBC_SNR_Ratio               -0.0036      0.000    -13.264      0.000      -0.004
-0.003
```

```
avg_rainfall_millimeter -9.177e-06   1.38e-05     -0.666      0.506   -3.62e-05
1.78e-05
avg_cloud_coverage          0.0005      0.000      3.538      0.000       0.000
0.001
avg_temperature            -0.0010      0.000     -4.911      0.000      -0.001
-0.001
illit_share                 0.7881      0.020     38.846      0.000       0.748
0.828
female_share                0.5512      0.044     12.523      0.000       0.465
0.637
popul_000s                8.958e-05    2.6e-05      3.447      0.001    3.86e-05
0.000
share_catholic1921         -0.2390      0.005    -50.378      0.000      -0.248
-0.230
share_socialist1921         0.1363      0.004     31.316      0.000       0.128
0.145
share_republican1921       -0.2455      0.021    -11.609      0.000      -0.287
-0.204
share_communist1921        -0.0631      0.013     -4.744      0.000      -0.089
-0.037
share_independent1921      -1.1105      0.259     -4.295      0.000      -1.617
-0.604
share_altri1921             1.8716      0.263      7.118      0.000       1.356
2.387
==============================================================================
Omnibus:                     7562.475   Durbin-Watson:                   1.132
Prob(Omnibus):                  0.000   Jarque-Bera (JB):            10568.310
Skew:                           0.906   Prob(JB):                         0.00
Kurtosis:                       3.741   Cond. No.                     3.79e+04
==============================================================================

Notes:
[1] Standard Errors assume that the covariance matrix of the errors is correctly
specified.
[2] The condition number is large, 3.79e+04. This might indicate that there are
strong multicollinearity or other numerical problems.
                            OLS Regression Results
==============================================================================
==
Dep. Variable:     violence_episode_total   R-squared:
0.051
Model:                                OLS   Adj. R-squared:
0.051
Method:                     Least Squares   F-statistic:
272.3
Date:                   Fri, 20 Dec 2024   Prob (F-statistic):
0.00
Time:                           06:26:24   Log-Likelihood:
```

-22456.
No. Observations: 66141 AIC:
4.494e+04
Df Residuals: 66127 BIC:
4.507e+04
Df Model: 13
Covariance Type: nonrobust

	coef	std err	t	P>|t|	[0.025	0.975]
const	0.1756	0.053	3.305	0.001	0.071	0.280
BBC_SNR_Ratio	-0.0038	0.001	-5.718	0.000	-0.005	-0.002
avg_rainfall_millimeter	2.08e-05	2.2e-05	0.944	0.345	-2.24e-05	6.4e-05
avg_cloud_coverage	-0.0028	0.000	-11.059	0.000	-0.003	-0.002
avg_temperature	-0.0022	0.000	-6.417	0.000	-0.003	-0.002
illit_share	0.5943	0.109	5.427	0.000	0.380	0.809
female_share	0.6193	0.098	6.317	0.000	0.427	0.811
popul_000s	0.0021	4.36e-05	47.325	0.000	0.002	0.002
share_catholic1921	-0.0678	0.033	-2.087	0.037	-0.132	-0.004
share_socialist1921	0.0504	0.020	2.586	0.010	0.012	0.089
share_republican1921	0.3094	0.046	6.678	0.000	0.219	0.400
share_communist1921	-0.0071	0.023	-0.314	0.754	-0.052	0.037
share_independent1921	-0.5065	0.362	-1.398	0.162	-1.217	0.203
share_altri1921	-0.8728	0.240	-3.632	0.000	-1.344	-0.402
illit_share_hat	-0.2882	0.133	-2.169	0.030	-0.549	-0.028

Omnibus:	123996.303	Durbin-Watson:	1.846
Prob(Omnibus):	0.000	Jarque-Bera (JB):	378892887.747
Skew:	14.113	Prob(JB):	0.00
Kurtosis:	372.714	Cond. No.	1.70e+18

```
==============================================================================

Notes:
[1] Standard Errors assume that the covariance matrix of the errors is correctly
specified.
[2] The smallest eigenvalue is 3.27e-28. This might indicate that there are
strong multicollinearity problems or that the design matrix is singular.
```

[Models 3 & 4] LASSO

[27]:
```
lasso_ridge_1921 = reg_data.loc[:, reg_data.columns.str.contains('|'.
 ↪join(controls_1921 + ['violence_episode_total']))]
model_spec = MS(lasso_ridge_1921.columns.drop('violence_episode_total')).
 ↪fit(lasso_ridge_1921)
dep = np.array(lasso_ridge_1921['violence_episode_total'])
expl_mf = model_spec.fit_transform(lasso_ridge_1921).drop('intercept', axis = 1)
expl = np.asarray(expl_mf)

expl_scaled = (expl - expl.mean(0)[None,:]) / (np.where(expl.std(0) == 0,␣
 ↪1e-10, expl.std(0)))[None, :]

reg_lambda = 10**np.linspace(9, -1, 100) / dep.std()

ridge_reg = skl.ElasticNet.path(expl_scaled,
                                dep,
                                l1_ratio=0.,
                                alphas=reg_lambda)[1]
```

```
/opt/conda/lib/python3.11/site-
packages/sklearn/linear_model/_coordinate_descent.py:614: UserWarning:
Coordinate descent without L1 regularization may lead to unexpected results and
is discouraged. Set l1_ratio > 0 to add L1 regularization.
  model = cd_fast.enet_coordinate_descent_gram(
/opt/conda/lib/python3.11/site-
packages/sklearn/linear_model/_coordinate_descent.py:614: ConvergenceWarning:
Objective did not converge. You might want to increase the number of iterations.
Duality gap: 4114.499999907954, tolerance: 0.8229000000000001
  model = cd_fast.enet_coordinate_descent_gram(
/opt/conda/lib/python3.11/site-
packages/sklearn/linear_model/_coordinate_descent.py:614: UserWarning:
Coordinate descent without L1 regularization may lead to unexpected results and
is discouraged. Set l1_ratio > 0 to add L1 regularization.
  model = cd_fast.enet_coordinate_descent_gram(
/opt/conda/lib/python3.11/site-
packages/sklearn/linear_model/_coordinate_descent.py:614: ConvergenceWarning:
Objective did not converge. You might want to increase the number of iterations.
Duality gap: 4114.499999883852, tolerance: 0.8229000000000001
  model = cd_fast.enet_coordinate_descent_gram(
```

```
/opt/conda/lib/python3.11/site-
packages/sklearn/linear_model/_coordinate_descent.py:614: UserWarning:
Coordinate descent without L1 regularization may lead to unexpected results and
is discouraged. Set l1_ratio > 0 to add L1 regularization.
  model = cd_fast.enet_coordinate_descent_gram(
/opt/conda/lib/python3.11/site-
packages/sklearn/linear_model/_coordinate_descent.py:614: ConvergenceWarning:
Objective did not converge. You might want to increase the number of iterations.
Duality gap: 4114.499999853438, tolerance: 0.8229000000000001
  model = cd_fast.enet_coordinate_descent_gram(
/opt/conda/lib/python3.11/site-
packages/sklearn/linear_model/_coordinate_descent.py:614: UserWarning:
Coordinate descent without L1 regularization may lead to unexpected results and
is discouraged. Set l1_ratio > 0 to add L1 regularization.
  model = cd_fast.enet_coordinate_descent_gram(
/opt/conda/lib/python3.11/site-
packages/sklearn/linear_model/_coordinate_descent.py:614: ConvergenceWarning:
Objective did not converge. You might want to increase the number of iterations.
Duality gap: 4114.499999815059, tolerance: 0.8229000000000001
  model = cd_fast.enet_coordinate_descent_gram(
/opt/conda/lib/python3.11/site-
packages/sklearn/linear_model/_coordinate_descent.py:614: UserWarning:
Coordinate descent without L1 regularization may lead to unexpected results and
is discouraged. Set l1_ratio > 0 to add L1 regularization.
  model = cd_fast.enet_coordinate_descent_gram(
/opt/conda/lib/python3.11/site-
packages/sklearn/linear_model/_coordinate_descent.py:614: ConvergenceWarning:
Objective did not converge. You might want to increase the number of iterations.
Duality gap: 4114.49999976663, tolerance: 0.8229000000000001
  model = cd_fast.enet_coordinate_descent_gram(
/opt/conda/lib/python3.11/site-
packages/sklearn/linear_model/_coordinate_descent.py:614: UserWarning:
Coordinate descent without L1 regularization may lead to unexpected results and
is discouraged. Set l1_ratio > 0 to add L1 regularization.
  model = cd_fast.enet_coordinate_descent_gram(
/opt/conda/lib/python3.11/site-
packages/sklearn/linear_model/_coordinate_descent.py:614: ConvergenceWarning:
Objective did not converge. You might want to increase the number of iterations.
Duality gap: 4114.499999705521, tolerance: 0.8229000000000001
  model = cd_fast.enet_coordinate_descent_gram(
/opt/conda/lib/python3.11/site-
packages/sklearn/linear_model/_coordinate_descent.py:614: UserWarning:
Coordinate descent without L1 regularization may lead to unexpected results and
is discouraged. Set l1_ratio > 0 to add L1 regularization.
  model = cd_fast.enet_coordinate_descent_gram(
/opt/conda/lib/python3.11/site-
packages/sklearn/linear_model/_coordinate_descent.py:614: ConvergenceWarning:
Objective did not converge. You might want to increase the number of iterations.
```

```
Duality gap: 4114.4999996284105, tolerance: 0.8229000000000001
  model = cd_fast.enet_coordinate_descent_gram(
/opt/conda/lib/python3.11/site-
packages/sklearn/linear_model/_coordinate_descent.py:614: UserWarning:
Coordinate descent without L1 regularization may lead to unexpected results and
is discouraged. Set l1_ratio > 0 to add L1 regularization.
  model = cd_fast.enet_coordinate_descent_gram(
/opt/conda/lib/python3.11/site-
packages/sklearn/linear_model/_coordinate_descent.py:614: ConvergenceWarning:
Objective did not converge. You might want to increase the number of iterations.
Duality gap: 4114.499999531106, tolerance: 0.8229000000000001
  model = cd_fast.enet_coordinate_descent_gram(
/opt/conda/lib/python3.11/site-
packages/sklearn/linear_model/_coordinate_descent.py:614: UserWarning:
Coordinate descent without L1 regularization may lead to unexpected results and
is discouraged. Set l1_ratio > 0 to add L1 regularization.
  model = cd_fast.enet_coordinate_descent_gram(
/opt/conda/lib/python3.11/site-
packages/sklearn/linear_model/_coordinate_descent.py:614: ConvergenceWarning:
Objective did not converge. You might want to increase the number of iterations.
Duality gap: 4114.499999408323, tolerance: 0.8229000000000001
  model = cd_fast.enet_coordinate_descent_gram(
/opt/conda/lib/python3.11/site-
packages/sklearn/linear_model/_coordinate_descent.py:614: UserWarning:
Coordinate descent without L1 regularization may lead to unexpected results and
is discouraged. Set l1_ratio > 0 to add L1 regularization.
  model = cd_fast.enet_coordinate_descent_gram(
/opt/conda/lib/python3.11/site-
packages/sklearn/linear_model/_coordinate_descent.py:614: ConvergenceWarning:
Objective did not converge. You might want to increase the number of iterations.
Duality gap: 4114.499999253389, tolerance: 0.8229000000000001
  model = cd_fast.enet_coordinate_descent_gram(
/opt/conda/lib/python3.11/site-
packages/sklearn/linear_model/_coordinate_descent.py:614: UserWarning:
Coordinate descent without L1 regularization may lead to unexpected results and
is discouraged. Set l1_ratio > 0 to add L1 regularization.
  model = cd_fast.enet_coordinate_descent_gram(
/opt/conda/lib/python3.11/site-
packages/sklearn/linear_model/_coordinate_descent.py:614: ConvergenceWarning:
Objective did not converge. You might want to increase the number of iterations.
Duality gap: 4114.4999990578835, tolerance: 0.8229000000000001
  model = cd_fast.enet_coordinate_descent_gram(
/opt/conda/lib/python3.11/site-
packages/sklearn/linear_model/_coordinate_descent.py:614: UserWarning:
Coordinate descent without L1 regularization may lead to unexpected results and
is discouraged. Set l1_ratio > 0 to add L1 regularization.
  model = cd_fast.enet_coordinate_descent_gram(
/opt/conda/lib/python3.11/site-
```

```
packages/sklearn/linear_model/_coordinate_descent.py:614: ConvergenceWarning:
Objective did not converge. You might want to increase the number of iterations.
Duality gap: 4114.499998811184, tolerance: 0.8229000000000001
  model = cd_fast.enet_coordinate_descent_gram(
/opt/conda/lib/python3.11/site-
packages/sklearn/linear_model/_coordinate_descent.py:614: UserWarning:
Coordinate descent without L1 regularization may lead to unexpected results and
is discouraged. Set l1_ratio > 0 to add L1 regularization.
  model = cd_fast.enet_coordinate_descent_gram(
/opt/conda/lib/python3.11/site-
packages/sklearn/linear_model/_coordinate_descent.py:614: ConvergenceWarning:
Objective did not converge. You might want to increase the number of iterations.
Duality gap: 4114.499998499884, tolerance: 0.8229000000000001
  model = cd_fast.enet_coordinate_descent_gram(
/opt/conda/lib/python3.11/site-
packages/sklearn/linear_model/_coordinate_descent.py:614: UserWarning:
Coordinate descent without L1 regularization may lead to unexpected results and
is discouraged. Set l1_ratio > 0 to add L1 regularization.
  model = cd_fast.enet_coordinate_descent_gram(
/opt/conda/lib/python3.11/site-
packages/sklearn/linear_model/_coordinate_descent.py:614: ConvergenceWarning:
Objective did not converge. You might want to increase the number of iterations.
Duality gap: 4114.499998107069, tolerance: 0.8229000000000001
  model = cd_fast.enet_coordinate_descent_gram(
/opt/conda/lib/python3.11/site-
packages/sklearn/linear_model/_coordinate_descent.py:614: UserWarning:
Coordinate descent without L1 regularization may lead to unexpected results and
is discouraged. Set l1_ratio > 0 to add L1 regularization.
  model = cd_fast.enet_coordinate_descent_gram(
/opt/conda/lib/python3.11/site-
packages/sklearn/linear_model/_coordinate_descent.py:614: ConvergenceWarning:
Objective did not converge. You might want to increase the number of iterations.
Duality gap: 4114.499997611391, tolerance: 0.8229000000000001
  model = cd_fast.enet_coordinate_descent_gram(
/opt/conda/lib/python3.11/site-
packages/sklearn/linear_model/_coordinate_descent.py:614: UserWarning:
Coordinate descent without L1 regularization may lead to unexpected results and
is discouraged. Set l1_ratio > 0 to add L1 regularization.
  model = cd_fast.enet_coordinate_descent_gram(
/opt/conda/lib/python3.11/site-
packages/sklearn/linear_model/_coordinate_descent.py:614: ConvergenceWarning:
Objective did not converge. You might want to increase the number of iterations.
Duality gap: 4114.499996985917, tolerance: 0.8229000000000001
  model = cd_fast.enet_coordinate_descent_gram(
/opt/conda/lib/python3.11/site-
packages/sklearn/linear_model/_coordinate_descent.py:614: UserWarning:
Coordinate descent without L1 regularization may lead to unexpected results and
is discouraged. Set l1_ratio > 0 to add L1 regularization.
```

```
  model = cd_fast.enet_coordinate_descent_gram(
/opt/conda/lib/python3.11/site-
packages/sklearn/linear_model/_coordinate_descent.py:614: ConvergenceWarning:
Objective did not converge. You might want to increase the number of iterations.
Duality gap: 4114.49999619666, tolerance: 0.8229000000000001
  model = cd_fast.enet_coordinate_descent_gram(
/opt/conda/lib/python3.11/site-
packages/sklearn/linear_model/_coordinate_descent.py:614: UserWarning:
Coordinate descent without L1 regularization may lead to unexpected results and
is discouraged. Set l1_ratio > 0 to add L1 regularization.
  model = cd_fast.enet_coordinate_descent_gram(
/opt/conda/lib/python3.11/site-
packages/sklearn/linear_model/_coordinate_descent.py:614: ConvergenceWarning:
Objective did not converge. You might want to increase the number of iterations.
Duality gap: 4114.499995200728, tolerance: 0.8229000000000001
  model = cd_fast.enet_coordinate_descent_gram(
/opt/conda/lib/python3.11/site-
packages/sklearn/linear_model/_coordinate_descent.py:614: UserWarning:
Coordinate descent without L1 regularization may lead to unexpected results and
is discouraged. Set l1_ratio > 0 to add L1 regularization.
  model = cd_fast.enet_coordinate_descent_gram(
/opt/conda/lib/python3.11/site-
packages/sklearn/linear_model/_coordinate_descent.py:614: ConvergenceWarning:
Objective did not converge. You might want to increase the number of iterations.
Duality gap: 4114.499993944007, tolerance: 0.8229000000000001
  model = cd_fast.enet_coordinate_descent_gram(
/opt/conda/lib/python3.11/site-
packages/sklearn/linear_model/_coordinate_descent.py:614: UserWarning:
Coordinate descent without L1 regularization may lead to unexpected results and
is discouraged. Set l1_ratio > 0 to add L1 regularization.
  model = cd_fast.enet_coordinate_descent_gram(
/opt/conda/lib/python3.11/site-
packages/sklearn/linear_model/_coordinate_descent.py:614: ConvergenceWarning:
Objective did not converge. You might want to increase the number of iterations.
Duality gap: 4114.499992358204, tolerance: 0.8229000000000001
  model = cd_fast.enet_coordinate_descent_gram(
/opt/conda/lib/python3.11/site-
packages/sklearn/linear_model/_coordinate_descent.py:614: UserWarning:
Coordinate descent without L1 regularization may lead to unexpected results and
is discouraged. Set l1_ratio > 0 to add L1 regularization.
  model = cd_fast.enet_coordinate_descent_gram(
/opt/conda/lib/python3.11/site-
packages/sklearn/linear_model/_coordinate_descent.py:614: ConvergenceWarning:
Objective did not converge. You might want to increase the number of iterations.
Duality gap: 4114.499990357147, tolerance: 0.8229000000000001
  model = cd_fast.enet_coordinate_descent_gram(
/opt/conda/lib/python3.11/site-
packages/sklearn/linear_model/_coordinate_descent.py:614: UserWarning:
```

```
Coordinate descent without L1 regularization may lead to unexpected results and
is discouraged. Set l1_ratio > 0 to add L1 regularization.
  model = cd_fast.enet_coordinate_descent_gram(
/opt/conda/lib/python3.11/site-
packages/sklearn/linear_model/_coordinate_descent.py:614: ConvergenceWarning:
Objective did not converge. You might want to increase the number of iterations.
Duality gap: 4114.4999878321, tolerance: 0.8229000000000001
  model = cd_fast.enet_coordinate_descent_gram(
/opt/conda/lib/python3.11/site-
packages/sklearn/linear_model/_coordinate_descent.py:614: UserWarning:
Coordinate descent without L1 regularization may lead to unexpected results and
is discouraged. Set l1_ratio > 0 to add L1 regularization.
  model = cd_fast.enet_coordinate_descent_gram(
/opt/conda/lib/python3.11/site-
packages/sklearn/linear_model/_coordinate_descent.py:614: ConvergenceWarning:
Objective did not converge. You might want to increase the number of iterations.
Duality gap: 4114.499984645851, tolerance: 0.8229000000000001
  model = cd_fast.enet_coordinate_descent_gram(
/opt/conda/lib/python3.11/site-
packages/sklearn/linear_model/_coordinate_descent.py:614: UserWarning:
Coordinate descent without L1 regularization may lead to unexpected results and
is discouraged. Set l1_ratio > 0 to add L1 regularization.
  model = cd_fast.enet_coordinate_descent_gram(
/opt/conda/lib/python3.11/site-
packages/sklearn/linear_model/_coordinate_descent.py:614: ConvergenceWarning:
Objective did not converge. You might want to increase the number of iterations.
Duality gap: 4114.499980625262, tolerance: 0.8229000000000001
  model = cd_fast.enet_coordinate_descent_gram(
/opt/conda/lib/python3.11/site-
packages/sklearn/linear_model/_coordinate_descent.py:614: UserWarning:
Coordinate descent without L1 regularization may lead to unexpected results and
is discouraged. Set l1_ratio > 0 to add L1 regularization.
  model = cd_fast.enet_coordinate_descent_gram(
/opt/conda/lib/python3.11/site-
packages/sklearn/linear_model/_coordinate_descent.py:614: ConvergenceWarning:
Objective did not converge. You might want to increase the number of iterations.
Duality gap: 4114.499975551854, tolerance: 0.8229000000000001
  model = cd_fast.enet_coordinate_descent_gram(
/opt/conda/lib/python3.11/site-
packages/sklearn/linear_model/_coordinate_descent.py:614: UserWarning:
Coordinate descent without L1 regularization may lead to unexpected results and
is discouraged. Set l1_ratio > 0 to add L1 regularization.
  model = cd_fast.enet_coordinate_descent_gram(
/opt/conda/lib/python3.11/site-
packages/sklearn/linear_model/_coordinate_descent.py:614: ConvergenceWarning:
Objective did not converge. You might want to increase the number of iterations.
Duality gap: 4114.499969149939, tolerance: 0.8229000000000001
  model = cd_fast.enet_coordinate_descent_gram(
```

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/opt/conda/lib/python3.11/site-
packages/sklearn/linear_model/_coordinate_descent.py:614: UserWarning:
Coordinate descent without L1 regularization may lead to unexpected results and
is discouraged. Set l1_ratio > 0 to add L1 regularization.
  model = cd_fast.enet_coordinate_descent_gram(
/opt/conda/lib/python3.11/site-
packages/sklearn/linear_model/_coordinate_descent.py:614: ConvergenceWarning:
Objective did not converge. You might want to increase the number of iterations.
Duality gap: 4114.49996107164, tolerance: 0.8229000000000001
  model = cd_fast.enet_coordinate_descent_gram(
/opt/conda/lib/python3.11/site-
packages/sklearn/linear_model/_coordinate_descent.py:614: UserWarning:
Coordinate descent without L1 regularization may lead to unexpected results and
is discouraged. Set l1_ratio > 0 to add L1 regularization.
  model = cd_fast.enet_coordinate_descent_gram(
/opt/conda/lib/python3.11/site-
packages/sklearn/linear_model/_coordinate_descent.py:614: ConvergenceWarning:
Objective did not converge. You might want to increase the number of iterations.
Duality gap: 4114.499950877985, tolerance: 0.8229000000000001
  model = cd_fast.enet_coordinate_descent_gram(
/opt/conda/lib/python3.11/site-
packages/sklearn/linear_model/_coordinate_descent.py:614: UserWarning:
Coordinate descent without L1 regularization may lead to unexpected results and
is discouraged. Set l1_ratio > 0 to add L1 regularization.
  model = cd_fast.enet_coordinate_descent_gram(
/opt/conda/lib/python3.11/site-
packages/sklearn/linear_model/_coordinate_descent.py:614: ConvergenceWarning:
Objective did not converge. You might want to increase the number of iterations.
Duality gap: 4114.499938015051, tolerance: 0.8229000000000001
  model = cd_fast.enet_coordinate_descent_gram(
/opt/conda/lib/python3.11/site-
packages/sklearn/linear_model/_coordinate_descent.py:614: UserWarning:
Coordinate descent without L1 regularization may lead to unexpected results and
is discouraged. Set l1_ratio > 0 to add L1 regularization.
  model = cd_fast.enet_coordinate_descent_gram(
/opt/conda/lib/python3.11/site-
packages/sklearn/linear_model/_coordinate_descent.py:614: ConvergenceWarning:
Objective did not converge. You might want to increase the number of iterations.
Duality gap: 4114.499921783874, tolerance: 0.8229000000000001
  model = cd_fast.enet_coordinate_descent_gram(
/opt/conda/lib/python3.11/site-
packages/sklearn/linear_model/_coordinate_descent.py:614: UserWarning:
Coordinate descent without L1 regularization may lead to unexpected results and
is discouraged. Set l1_ratio > 0 to add L1 regularization.
  model = cd_fast.enet_coordinate_descent_gram(
/opt/conda/lib/python3.11/site-
packages/sklearn/linear_model/_coordinate_descent.py:614: ConvergenceWarning:
Objective did not converge. You might want to increase the number of iterations.
```

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Duality gap: 4114.499901302455, tolerance: 0.8229000000000001
  model = cd_fast.enet_coordinate_descent_gram(
/opt/conda/lib/python3.11/site-
packages/sklearn/linear_model/_coordinate_descent.py:614: UserWarning:
Coordinate descent without L1 regularization may lead to unexpected results and
is discouraged. Set l1_ratio > 0 to add L1 regularization.
  model = cd_fast.enet_coordinate_descent_gram(
/opt/conda/lib/python3.11/site-
packages/sklearn/linear_model/_coordinate_descent.py:614: ConvergenceWarning:
Objective did not converge. You might want to increase the number of iterations.
Duality gap: 4114.499875457842, tolerance: 0.8229000000000001
  model = cd_fast.enet_coordinate_descent_gram(
/opt/conda/lib/python3.11/site-
packages/sklearn/linear_model/_coordinate_descent.py:614: UserWarning:
Coordinate descent without L1 regularization may lead to unexpected results and
is discouraged. Set l1_ratio > 0 to add L1 regularization.
  model = cd_fast.enet_coordinate_descent_gram(
/opt/conda/lib/python3.11/site-
packages/sklearn/linear_model/_coordinate_descent.py:614: ConvergenceWarning:
Objective did not converge. You might want to increase the number of iterations.
Duality gap: 4114.499842845651, tolerance: 0.8229000000000001
  model = cd_fast.enet_coordinate_descent_gram(
/opt/conda/lib/python3.11/site-
packages/sklearn/linear_model/_coordinate_descent.py:614: UserWarning:
Coordinate descent without L1 regularization may lead to unexpected results and
is discouraged. Set l1_ratio > 0 to add L1 regularization.
  model = cd_fast.enet_coordinate_descent_gram(
/opt/conda/lib/python3.11/site-
packages/sklearn/linear_model/_coordinate_descent.py:614: ConvergenceWarning:
Objective did not converge. You might want to increase the number of iterations.
Duality gap: 4114.4998016937525, tolerance: 0.8229000000000001
  model = cd_fast.enet_coordinate_descent_gram(
/opt/conda/lib/python3.11/site-
packages/sklearn/linear_model/_coordinate_descent.py:614: UserWarning:
Coordinate descent without L1 regularization may lead to unexpected results and
is discouraged. Set l1_ratio > 0 to add L1 regularization.
  model = cd_fast.enet_coordinate_descent_gram(
/opt/conda/lib/python3.11/site-
packages/sklearn/linear_model/_coordinate_descent.py:614: ConvergenceWarning:
Objective did not converge. You might want to increase the number of iterations.
Duality gap: 4114.499749765974, tolerance: 0.8229000000000001
  model = cd_fast.enet_coordinate_descent_gram(
/opt/conda/lib/python3.11/site-
packages/sklearn/linear_model/_coordinate_descent.py:614: UserWarning:
Coordinate descent without L1 regularization may lead to unexpected results and
is discouraged. Set l1_ratio > 0 to add L1 regularization.
  model = cd_fast.enet_coordinate_descent_gram(
/opt/conda/lib/python3.11/site-
```

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packages/sklearn/linear_model/_coordinate_descent.py:614: ConvergenceWarning:
Objective did not converge. You might want to increase the number of iterations.
Duality gap: 4114.499684240594, tolerance: 0.8229000000000001
  model = cd_fast.enet_coordinate_descent_gram(
/opt/conda/lib/python3.11/site-
packages/sklearn/linear_model/_coordinate_descent.py:614: UserWarning:
Coordinate descent without L1 regularization may lead to unexpected results and
is discouraged. Set l1_ratio > 0 to add L1 regularization.
  model = cd_fast.enet_coordinate_descent_gram(
/opt/conda/lib/python3.11/site-
packages/sklearn/linear_model/_coordinate_descent.py:614: ConvergenceWarning:
Objective did not converge. You might want to increase the number of iterations.
Duality gap: 4114.499601557017, tolerance: 0.8229000000000001
  model = cd_fast.enet_coordinate_descent_gram(
/opt/conda/lib/python3.11/site-
packages/sklearn/linear_model/_coordinate_descent.py:614: UserWarning:
Coordinate descent without L1 regularization may lead to unexpected results and
is discouraged. Set l1_ratio > 0 to add L1 regularization.
  model = cd_fast.enet_coordinate_descent_gram(
/opt/conda/lib/python3.11/site-
packages/sklearn/linear_model/_coordinate_descent.py:614: ConvergenceWarning:
Objective did not converge. You might want to increase the number of iterations.
Duality gap: 4114.49949722229, tolerance: 0.8229000000000001
  model = cd_fast.enet_coordinate_descent_gram(
/opt/conda/lib/python3.11/site-
packages/sklearn/linear_model/_coordinate_descent.py:614: UserWarning:
Coordinate descent without L1 regularization may lead to unexpected results and
is discouraged. Set l1_ratio > 0 to add L1 regularization.
  model = cd_fast.enet_coordinate_descent_gram(
/opt/conda/lib/python3.11/site-
packages/sklearn/linear_model/_coordinate_descent.py:614: ConvergenceWarning:
Objective did not converge. You might want to increase the number of iterations.
Duality gap: 4114.499365566982, tolerance: 0.8229000000000001
  model = cd_fast.enet_coordinate_descent_gram(
/opt/conda/lib/python3.11/site-
packages/sklearn/linear_model/_coordinate_descent.py:614: UserWarning:
Coordinate descent without L1 regularization may lead to unexpected results and
is discouraged. Set l1_ratio > 0 to add L1 regularization.
  model = cd_fast.enet_coordinate_descent_gram(
/opt/conda/lib/python3.11/site-
packages/sklearn/linear_model/_coordinate_descent.py:614: ConvergenceWarning:
Objective did not converge. You might want to increase the number of iterations.
Duality gap: 4114.499199437119, tolerance: 0.8229000000000001
  model = cd_fast.enet_coordinate_descent_gram(
/opt/conda/lib/python3.11/site-
packages/sklearn/linear_model/_coordinate_descent.py:614: UserWarning:
Coordinate descent without L1 regularization may lead to unexpected results and
is discouraged. Set l1_ratio > 0 to add L1 regularization.
```

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  model = cd_fast.enet_coordinate_descent_gram(
/opt/conda/lib/python3.11/site-
packages/sklearn/linear_model/_coordinate_descent.py:614: ConvergenceWarning:
Objective did not converge. You might want to increase the number of iterations.
Duality gap: 4114.498989805477, tolerance: 0.8229000000000001
  model = cd_fast.enet_coordinate_descent_gram(
/opt/conda/lib/python3.11/site-
packages/sklearn/linear_model/_coordinate_descent.py:614: UserWarning:
Coordinate descent without L1 regularization may lead to unexpected results and
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  model = cd_fast.enet_coordinate_descent_gram(
/opt/conda/lib/python3.11/site-
packages/sklearn/linear_model/_coordinate_descent.py:614: ConvergenceWarning:
Objective did not converge. You might want to increase the number of iterations.
Duality gap: 4114.4987252810915, tolerance: 0.8229000000000001
  model = cd_fast.enet_coordinate_descent_gram(
/opt/conda/lib/python3.11/site-
packages/sklearn/linear_model/_coordinate_descent.py:614: UserWarning:
Coordinate descent without L1 regularization may lead to unexpected results and
is discouraged. Set l1_ratio > 0 to add L1 regularization.
  model = cd_fast.enet_coordinate_descent_gram(
/opt/conda/lib/python3.11/site-
packages/sklearn/linear_model/_coordinate_descent.py:614: ConvergenceWarning:
Objective did not converge. You might want to increase the number of iterations.
Duality gap: 4114.498391490361, tolerance: 0.8229000000000001
  model = cd_fast.enet_coordinate_descent_gram(
/opt/conda/lib/python3.11/site-
packages/sklearn/linear_model/_coordinate_descent.py:614: UserWarning:
Coordinate descent without L1 regularization may lead to unexpected results and
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  model = cd_fast.enet_coordinate_descent_gram(
/opt/conda/lib/python3.11/site-
packages/sklearn/linear_model/_coordinate_descent.py:614: ConvergenceWarning:
Objective did not converge. You might want to increase the number of iterations.
Duality gap: 4114.497970296119, tolerance: 0.8229000000000001
  model = cd_fast.enet_coordinate_descent_gram(
/opt/conda/lib/python3.11/site-
packages/sklearn/linear_model/_coordinate_descent.py:614: UserWarning:
Coordinate descent without L1 regularization may lead to unexpected results and
is discouraged. Set l1_ratio > 0 to add L1 regularization.
  model = cd_fast.enet_coordinate_descent_gram(
/opt/conda/lib/python3.11/site-
packages/sklearn/linear_model/_coordinate_descent.py:614: ConvergenceWarning:
Objective did not converge. You might want to increase the number of iterations.
Duality gap: 4114.497438812274, tolerance: 0.8229000000000001
  model = cd_fast.enet_coordinate_descent_gram(
/opt/conda/lib/python3.11/site-
packages/sklearn/linear_model/_coordinate_descent.py:614: UserWarning:
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Coordinate descent without L1 regularization may lead to unexpected results and
is discouraged. Set l1_ratio > 0 to add L1 regularization.
  model = cd_fast.enet_coordinate_descent_gram(
/opt/conda/lib/python3.11/site-
packages/sklearn/linear_model/_coordinate_descent.py:614: ConvergenceWarning:
Objective did not converge. You might want to increase the number of iterations.
Duality gap: 4114.496768160513, tolerance: 0.8229000000000001
  model = cd_fast.enet_coordinate_descent_gram(
/opt/conda/lib/python3.11/site-
packages/sklearn/linear_model/_coordinate_descent.py:614: UserWarning:
Coordinate descent without L1 regularization may lead to unexpected results and
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  model = cd_fast.enet_coordinate_descent_gram(
/opt/conda/lib/python3.11/site-
packages/sklearn/linear_model/_coordinate_descent.py:614: ConvergenceWarning:
Objective did not converge. You might want to increase the number of iterations.
Duality gap: 4114.4959219016, tolerance: 0.8229000000000001
  model = cd_fast.enet_coordinate_descent_gram(
/opt/conda/lib/python3.11/site-
packages/sklearn/linear_model/_coordinate_descent.py:614: UserWarning:
Coordinate descent without L1 regularization may lead to unexpected results and
is discouraged. Set l1_ratio > 0 to add L1 regularization.
  model = cd_fast.enet_coordinate_descent_gram(
/opt/conda/lib/python3.11/site-
packages/sklearn/linear_model/_coordinate_descent.py:614: ConvergenceWarning:
Objective did not converge. You might want to increase the number of iterations.
Duality gap: 4114.494854056109, tolerance: 0.8229000000000001
  model = cd_fast.enet_coordinate_descent_gram(
/opt/conda/lib/python3.11/site-
packages/sklearn/linear_model/_coordinate_descent.py:614: UserWarning:
Coordinate descent without L1 regularization may lead to unexpected results and
is discouraged. Set l1_ratio > 0 to add L1 regularization.
  model = cd_fast.enet_coordinate_descent_gram(
/opt/conda/lib/python3.11/site-
packages/sklearn/linear_model/_coordinate_descent.py:614: ConvergenceWarning:
Objective did not converge. You might want to increase the number of iterations.
Duality gap: 4114.493506607258, tolerance: 0.8229000000000001
  model = cd_fast.enet_coordinate_descent_gram(
/opt/conda/lib/python3.11/site-
packages/sklearn/linear_model/_coordinate_descent.py:614: UserWarning:
Coordinate descent without L1 regularization may lead to unexpected results and
is discouraged. Set l1_ratio > 0 to add L1 regularization.
  model = cd_fast.enet_coordinate_descent_gram(
/opt/conda/lib/python3.11/site-
packages/sklearn/linear_model/_coordinate_descent.py:614: ConvergenceWarning:
Objective did not converge. You might want to increase the number of iterations.
Duality gap: 4114.491806350434, tolerance: 0.8229000000000001
  model = cd_fast.enet_coordinate_descent_gram(
```

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/opt/conda/lib/python3.11/site-
packages/sklearn/linear_model/_coordinate_descent.py:614: UserWarning:
Coordinate descent without L1 regularization may lead to unexpected results and
is discouraged. Set l1_ratio > 0 to add L1 regularization.
  model = cd_fast.enet_coordinate_descent_gram(
/opt/conda/lib/python3.11/site-
packages/sklearn/linear_model/_coordinate_descent.py:614: ConvergenceWarning:
Objective did not converge. You might want to increase the number of iterations.
Duality gap: 4114.489660918672, tolerance: 0.8229000000000001
  model = cd_fast.enet_coordinate_descent_gram(
/opt/conda/lib/python3.11/site-
packages/sklearn/linear_model/_coordinate_descent.py:614: UserWarning:
Coordinate descent without L1 regularization may lead to unexpected results and
is discouraged. Set l1_ratio > 0 to add L1 regularization.
  model = cd_fast.enet_coordinate_descent_gram(
/opt/conda/lib/python3.11/site-
packages/sklearn/linear_model/_coordinate_descent.py:614: ConvergenceWarning:
Objective did not converge. You might want to increase the number of iterations.
Duality gap: 4114.486953768875, tolerance: 0.8229000000000001
  model = cd_fast.enet_coordinate_descent_gram(
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packages/sklearn/linear_model/_coordinate_descent.py:614: UserWarning:
Coordinate descent without L1 regularization may lead to unexpected results and
is discouraged. Set l1_ratio > 0 to add L1 regularization.
  model = cd_fast.enet_coordinate_descent_gram(
/opt/conda/lib/python3.11/site-
packages/sklearn/linear_model/_coordinate_descent.py:614: ConvergenceWarning:
Objective did not converge. You might want to increase the number of iterations.
Duality gap: 4114.483537857527, tolerance: 0.8229000000000001
  model = cd_fast.enet_coordinate_descent_gram(
/opt/conda/lib/python3.11/site-
packages/sklearn/linear_model/_coordinate_descent.py:614: UserWarning:
Coordinate descent without L1 regularization may lead to unexpected results and
is discouraged. Set l1_ratio > 0 to add L1 regularization.
  model = cd_fast.enet_coordinate_descent_gram(
/opt/conda/lib/python3.11/site-
packages/sklearn/linear_model/_coordinate_descent.py:614: ConvergenceWarning:
Objective did not converge. You might want to increase the number of iterations.
Duality gap: 4114.479227664115, tolerance: 0.8229000000000001
  model = cd_fast.enet_coordinate_descent_gram(
/opt/conda/lib/python3.11/site-
packages/sklearn/linear_model/_coordinate_descent.py:614: UserWarning:
Coordinate descent without L1 regularization may lead to unexpected results and
is discouraged. Set l1_ratio > 0 to add L1 regularization.
  model = cd_fast.enet_coordinate_descent_gram(
/opt/conda/lib/python3.11/site-
packages/sklearn/linear_model/_coordinate_descent.py:614: ConvergenceWarning:
Objective did not converge. You might want to increase the number of iterations.
```

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Duality gap: 4114.473789131869, tolerance: 0.8229000000000001
  model = cd_fast.enet_coordinate_descent_gram(
/opt/conda/lib/python3.11/site-
packages/sklearn/linear_model/_coordinate_descent.py:614: UserWarning:
Coordinate descent without L1 regularization may lead to unexpected results and
is discouraged. Set l1_ratio > 0 to add L1 regularization.
  model = cd_fast.enet_coordinate_descent_gram(
/opt/conda/lib/python3.11/site-
packages/sklearn/linear_model/_coordinate_descent.py:614: ConvergenceWarning:
Objective did not converge. You might want to increase the number of iterations.
Duality gap: 4114.466926984, tolerance: 0.8229000000000001
  model = cd_fast.enet_coordinate_descent_gram(
/opt/conda/lib/python3.11/site-
packages/sklearn/linear_model/_coordinate_descent.py:614: UserWarning:
Coordinate descent without L1 regularization may lead to unexpected results and
is discouraged. Set l1_ratio > 0 to add L1 regularization.
  model = cd_fast.enet_coordinate_descent_gram(
/opt/conda/lib/python3.11/site-
packages/sklearn/linear_model/_coordinate_descent.py:614: ConvergenceWarning:
Objective did not converge. You might want to increase the number of iterations.
Duality gap: 4114.458268733857, tolerance: 0.8229000000000001
  model = cd_fast.enet_coordinate_descent_gram(
/opt/conda/lib/python3.11/site-
packages/sklearn/linear_model/_coordinate_descent.py:614: UserWarning:
Coordinate descent without L1 regularization may lead to unexpected results and
is discouraged. Set l1_ratio > 0 to add L1 regularization.
  model = cd_fast.enet_coordinate_descent_gram(
/opt/conda/lib/python3.11/site-
packages/sklearn/linear_model/_coordinate_descent.py:614: ConvergenceWarning:
Objective did not converge. You might want to increase the number of iterations.
Duality gap: 4114.447344532325, tolerance: 0.8229000000000001
  model = cd_fast.enet_coordinate_descent_gram(
/opt/conda/lib/python3.11/site-
packages/sklearn/linear_model/_coordinate_descent.py:614: UserWarning:
Coordinate descent without L1 regularization may lead to unexpected results and
is discouraged. Set l1_ratio > 0 to add L1 regularization.
  model = cd_fast.enet_coordinate_descent_gram(
/opt/conda/lib/python3.11/site-
packages/sklearn/linear_model/_coordinate_descent.py:614: ConvergenceWarning:
Objective did not converge. You might want to increase the number of iterations.
Duality gap: 4114.433561776759, tolerance: 0.8229000000000001
  model = cd_fast.enet_coordinate_descent_gram(
/opt/conda/lib/python3.11/site-
packages/sklearn/linear_model/_coordinate_descent.py:614: UserWarning:
Coordinate descent without L1 regularization may lead to unexpected results and
is discouraged. Set l1_ratio > 0 to add L1 regularization.
  model = cd_fast.enet_coordinate_descent_gram(
/opt/conda/lib/python3.11/site-
```

```
packages/sklearn/linear_model/_coordinate_descent.py:614: ConvergenceWarning:
Objective did not converge. You might want to increase the number of iterations.
Duality gap: 4114.4161731325385, tolerance: 0.8229000000000001
  model = cd_fast.enet_coordinate_descent_gram(
/opt/conda/lib/python3.11/site-
packages/sklearn/linear_model/_coordinate_descent.py:614: UserWarning:
Coordinate descent without L1 regularization may lead to unexpected results and
is discouraged. Set l1_ratio > 0 to add L1 regularization.
  model = cd_fast.enet_coordinate_descent_gram(
/opt/conda/lib/python3.11/site-
packages/sklearn/linear_model/_coordinate_descent.py:614: ConvergenceWarning:
Objective did not converge. You might want to increase the number of iterations.
Duality gap: 4114.39423627859, tolerance: 0.8229000000000001
  model = cd_fast.enet_coordinate_descent_gram(
/opt/conda/lib/python3.11/site-
packages/sklearn/linear_model/_coordinate_descent.py:614: UserWarning:
Coordinate descent without L1 regularization may lead to unexpected results and
is discouraged. Set l1_ratio > 0 to add L1 regularization.
  model = cd_fast.enet_coordinate_descent_gram(
/opt/conda/lib/python3.11/site-
packages/sklearn/linear_model/_coordinate_descent.py:614: ConvergenceWarning:
Objective did not converge. You might want to increase the number of iterations.
Duality gap: 4114.366563267354, tolerance: 0.8229000000000001
  model = cd_fast.enet_coordinate_descent_gram(
/opt/conda/lib/python3.11/site-
packages/sklearn/linear_model/_coordinate_descent.py:614: UserWarning:
Coordinate descent without L1 regularization may lead to unexpected results and
is discouraged. Set l1_ratio > 0 to add L1 regularization.
  model = cd_fast.enet_coordinate_descent_gram(
/opt/conda/lib/python3.11/site-
packages/sklearn/linear_model/_coordinate_descent.py:614: ConvergenceWarning:
Objective did not converge. You might want to increase the number of iterations.
Duality gap: 4114.331656871238, tolerance: 0.8229000000000001
  model = cd_fast.enet_coordinate_descent_gram(
/opt/conda/lib/python3.11/site-
packages/sklearn/linear_model/_coordinate_descent.py:614: UserWarning:
Coordinate descent without L1 regularization may lead to unexpected results and
is discouraged. Set l1_ratio > 0 to add L1 regularization.
  model = cd_fast.enet_coordinate_descent_gram(
/opt/conda/lib/python3.11/site-
packages/sklearn/linear_model/_coordinate_descent.py:614: ConvergenceWarning:
Objective did not converge. You might want to increase the number of iterations.
Duality gap: 4114.287630653103, tolerance: 0.8229000000000001
  model = cd_fast.enet_coordinate_descent_gram(
/opt/conda/lib/python3.11/site-
packages/sklearn/linear_model/_coordinate_descent.py:614: UserWarning:
Coordinate descent without L1 regularization may lead to unexpected results and
is discouraged. Set l1_ratio > 0 to add L1 regularization.
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  model = cd_fast.enet_coordinate_descent_gram(
/opt/conda/lib/python3.11/site-
packages/sklearn/linear_model/_coordinate_descent.py:614: ConvergenceWarning:
Objective did not converge. You might want to increase the number of iterations.
Duality gap: 4114.232108729151, tolerance: 0.8229000000000001
  model = cd_fast.enet_coordinate_descent_gram(
/opt/conda/lib/python3.11/site-
packages/sklearn/linear_model/_coordinate_descent.py:614: UserWarning:
Coordinate descent without L1 regularization may lead to unexpected results and
is discouraged. Set l1_ratio > 0 to add L1 regularization.
  model = cd_fast.enet_coordinate_descent_gram(
/opt/conda/lib/python3.11/site-
packages/sklearn/linear_model/_coordinate_descent.py:614: ConvergenceWarning:
Objective did not converge. You might want to increase the number of iterations.
Duality gap: 4114.162100271251, tolerance: 0.8229000000000001
  model = cd_fast.enet_coordinate_descent_gram(
/opt/conda/lib/python3.11/site-
packages/sklearn/linear_model/_coordinate_descent.py:614: UserWarning:
Coordinate descent without L1 regularization may lead to unexpected results and
is discouraged. Set l1_ratio > 0 to add L1 regularization.
  model = cd_fast.enet_coordinate_descent_gram(
/opt/conda/lib/python3.11/site-
packages/sklearn/linear_model/_coordinate_descent.py:614: ConvergenceWarning:
Objective did not converge. You might want to increase the number of iterations.
Duality gap: 4114.07384271095, tolerance: 0.8229000000000001
  model = cd_fast.enet_coordinate_descent_gram(
/opt/conda/lib/python3.11/site-
packages/sklearn/linear_model/_coordinate_descent.py:614: UserWarning:
Coordinate descent without L1 regularization may lead to unexpected results and
is discouraged. Set l1_ratio > 0 to add L1 regularization.
  model = cd_fast.enet_coordinate_descent_gram(
/opt/conda/lib/python3.11/site-
packages/sklearn/linear_model/_coordinate_descent.py:614: ConvergenceWarning:
Objective did not converge. You might want to increase the number of iterations.
Duality gap: 4113.962606360118, tolerance: 0.8229000000000001
  model = cd_fast.enet_coordinate_descent_gram(
/opt/conda/lib/python3.11/site-
packages/sklearn/linear_model/_coordinate_descent.py:614: UserWarning:
Coordinate descent without L1 regularization may lead to unexpected results and
is discouraged. Set l1_ratio > 0 to add L1 regularization.
  model = cd_fast.enet_coordinate_descent_gram(
/opt/conda/lib/python3.11/site-
packages/sklearn/linear_model/_coordinate_descent.py:614: ConvergenceWarning:
Objective did not converge. You might want to increase the number of iterations.
Duality gap: 4113.822451779347, tolerance: 0.8229000000000001
  model = cd_fast.enet_coordinate_descent_gram(
/opt/conda/lib/python3.11/site-
packages/sklearn/linear_model/_coordinate_descent.py:614: UserWarning:
```

```
Coordinate descent without L1 regularization may lead to unexpected results and
is discouraged. Set l1_ratio > 0 to add L1 regularization.
  model = cd_fast.enet_coordinate_descent_gram(
/opt/conda/lib/python3.11/site-
packages/sklearn/linear_model/_coordinate_descent.py:614: ConvergenceWarning:
Objective did not converge. You might want to increase the number of iterations.
Duality gap: 4113.645929773615, tolerance: 0.8229000000000001
  model = cd_fast.enet_coordinate_descent_gram(
/opt/conda/lib/python3.11/site-
packages/sklearn/linear_model/_coordinate_descent.py:614: UserWarning:
Coordinate descent without L1 regularization may lead to unexpected results and
is discouraged. Set l1_ratio > 0 to add L1 regularization.
  model = cd_fast.enet_coordinate_descent_gram(
/opt/conda/lib/python3.11/site-
packages/sklearn/linear_model/_coordinate_descent.py:614: ConvergenceWarning:
Objective did not converge. You might want to increase the number of iterations.
Duality gap: 4113.42371251733, tolerance: 0.8229000000000001
  model = cd_fast.enet_coordinate_descent_gram(
/opt/conda/lib/python3.11/site-
packages/sklearn/linear_model/_coordinate_descent.py:614: UserWarning:
Coordinate descent without L1 regularization may lead to unexpected results and
is discouraged. Set l1_ratio > 0 to add L1 regularization.
  model = cd_fast.enet_coordinate_descent_gram(
/opt/conda/lib/python3.11/site-
packages/sklearn/linear_model/_coordinate_descent.py:614: ConvergenceWarning:
Objective did not converge. You might want to increase the number of iterations.
Duality gap: 4113.144143266286, tolerance: 0.8229000000000001
  model = cd_fast.enet_coordinate_descent_gram(
/opt/conda/lib/python3.11/site-
packages/sklearn/linear_model/_coordinate_descent.py:614: UserWarning:
Coordinate descent without L1 regularization may lead to unexpected results and
is discouraged. Set l1_ratio > 0 to add L1 regularization.
  model = cd_fast.enet_coordinate_descent_gram(
/opt/conda/lib/python3.11/site-
packages/sklearn/linear_model/_coordinate_descent.py:614: ConvergenceWarning:
Objective did not converge. You might want to increase the number of iterations.
Duality gap: 4112.792691842636, tolerance: 0.8229000000000001
  model = cd_fast.enet_coordinate_descent_gram(
/opt/conda/lib/python3.11/site-
packages/sklearn/linear_model/_coordinate_descent.py:614: UserWarning:
Coordinate descent without L1 regularization may lead to unexpected results and
is discouraged. Set l1_ratio > 0 to add L1 regularization.
  model = cd_fast.enet_coordinate_descent_gram(
/opt/conda/lib/python3.11/site-
packages/sklearn/linear_model/_coordinate_descent.py:614: ConvergenceWarning:
Objective did not converge. You might want to increase the number of iterations.
Duality gap: 4112.35130429172, tolerance: 0.8229000000000001
  model = cd_fast.enet_coordinate_descent_gram(
```

```
/opt/conda/lib/python3.11/site-
packages/sklearn/linear_model/_coordinate_descent.py:614: UserWarning:
Coordinate descent without L1 regularization may lead to unexpected results and
is discouraged. Set l1_ratio > 0 to add L1 regularization.
  model = cd_fast.enet_coordinate_descent_gram(
/opt/conda/lib/python3.11/site-
packages/sklearn/linear_model/_coordinate_descent.py:614: ConvergenceWarning:
Objective did not converge. You might want to increase the number of iterations.
Duality gap: 4111.797638902967, tolerance: 0.8229000000000001
  model = cd_fast.enet_coordinate_descent_gram(
/opt/conda/lib/python3.11/site-
packages/sklearn/linear_model/_coordinate_descent.py:614: UserWarning:
Coordinate descent without L1 regularization may lead to unexpected results and
is discouraged. Set l1_ratio > 0 to add L1 regularization.
  model = cd_fast.enet_coordinate_descent_gram(
/opt/conda/lib/python3.11/site-
packages/sklearn/linear_model/_coordinate_descent.py:614: ConvergenceWarning:
Objective did not converge. You might want to increase the number of iterations.
Duality gap: 4111.104188775848, tolerance: 0.8229000000000001
  model = cd_fast.enet_coordinate_descent_gram(
/opt/conda/lib/python3.11/site-
packages/sklearn/linear_model/_coordinate_descent.py:614: UserWarning:
Coordinate descent without L1 regularization may lead to unexpected results and
is discouraged. Set l1_ratio > 0 to add L1 regularization.
  model = cd_fast.enet_coordinate_descent_gram(
/opt/conda/lib/python3.11/site-
packages/sklearn/linear_model/_coordinate_descent.py:614: ConvergenceWarning:
Objective did not converge. You might want to increase the number of iterations.
Duality gap: 4110.237305546442, tolerance: 0.8229000000000001
  model = cd_fast.enet_coordinate_descent_gram(
/opt/conda/lib/python3.11/site-
packages/sklearn/linear_model/_coordinate_descent.py:614: UserWarning:
Coordinate descent without L1 regularization may lead to unexpected results and
is discouraged. Set l1_ratio > 0 to add L1 regularization.
  model = cd_fast.enet_coordinate_descent_gram(
/opt/conda/lib/python3.11/site-
packages/sklearn/linear_model/_coordinate_descent.py:614: ConvergenceWarning:
Objective did not converge. You might want to increase the number of iterations.
Duality gap: 4109.156162688667, tolerance: 0.8229000000000001
  model = cd_fast.enet_coordinate_descent_gram(
/opt/conda/lib/python3.11/site-
packages/sklearn/linear_model/_coordinate_descent.py:614: UserWarning:
Coordinate descent without L1 regularization may lead to unexpected results and
is discouraged. Set l1_ratio > 0 to add L1 regularization.
  model = cd_fast.enet_coordinate_descent_gram(
/opt/conda/lib/python3.11/site-
packages/sklearn/linear_model/_coordinate_descent.py:614: ConvergenceWarning:
Objective did not converge. You might want to increase the number of iterations.
```

```
Duality gap: 4107.811733352961, tolerance: 0.8229000000000001
  model = cd_fast.enet_coordinate_descent_gram(
/opt/conda/lib/python3.11/site-
packages/sklearn/linear_model/_coordinate_descent.py:614: UserWarning:
Coordinate descent without L1 regularization may lead to unexpected results and
is discouraged. Set l1_ratio > 0 to add L1 regularization.
  model = cd_fast.enet_coordinate_descent_gram(
/opt/conda/lib/python3.11/site-
packages/sklearn/linear_model/_coordinate_descent.py:614: ConvergenceWarning:
Objective did not converge. You might want to increase the number of iterations.
Duality gap: 4106.14591018942, tolerance: 0.8229000000000001
  model = cd_fast.enet_coordinate_descent_gram(
/opt/conda/lib/python3.11/site-
packages/sklearn/linear_model/_coordinate_descent.py:614: UserWarning:
Coordinate descent without L1 regularization may lead to unexpected results and
is discouraged. Set l1_ratio > 0 to add L1 regularization.
  model = cd_fast.enet_coordinate_descent_gram(
/opt/conda/lib/python3.11/site-
packages/sklearn/linear_model/_coordinate_descent.py:614: ConvergenceWarning:
Objective did not converge. You might want to increase the number of iterations.
Duality gap: 4104.090964524567, tolerance: 0.8229000000000001
  model = cd_fast.enet_coordinate_descent_gram(
/opt/conda/lib/python3.11/site-
packages/sklearn/linear_model/_coordinate_descent.py:614: UserWarning:
Coordinate descent without L1 regularization may lead to unexpected results and
is discouraged. Set l1_ratio > 0 to add L1 regularization.
  model = cd_fast.enet_coordinate_descent_gram(
/opt/conda/lib/python3.11/site-
packages/sklearn/linear_model/_coordinate_descent.py:614: ConvergenceWarning:
Objective did not converge. You might want to increase the number of iterations.
Duality gap: 4101.5696267937865, tolerance: 0.8229000000000001
  model = cd_fast.enet_coordinate_descent_gram(
/opt/conda/lib/python3.11/site-
packages/sklearn/linear_model/_coordinate_descent.py:614: UserWarning:
Coordinate descent without L1 regularization may lead to unexpected results and
is discouraged. Set l1_ratio > 0 to add L1 regularization.
  model = cd_fast.enet_coordinate_descent_gram(
/opt/conda/lib/python3.11/site-
packages/sklearn/linear_model/_coordinate_descent.py:614: ConvergenceWarning:
Objective did not converge. You might want to increase the number of iterations.
Duality gap: 4098.496158204311, tolerance: 0.8229000000000001
  model = cd_fast.enet_coordinate_descent_gram(
/opt/conda/lib/python3.11/site-
packages/sklearn/linear_model/_coordinate_descent.py:614: UserWarning:
Coordinate descent without L1 regularization may lead to unexpected results and
is discouraged. Set l1_ratio > 0 to add L1 regularization.
  model = cd_fast.enet_coordinate_descent_gram(
/opt/conda/lib/python3.11/site-
```

```
packages/sklearn/linear_model/_coordinate_descent.py:614: ConvergenceWarning:
Objective did not converge. You might want to increase the number of iterations.
Duality gap: 4094.778851411672, tolerance: 0.8229000000000001
  model = cd_fast.enet_coordinate_descent_gram(
/opt/conda/lib/python3.11/site-
packages/sklearn/linear_model/_coordinate_descent.py:614: UserWarning:
Coordinate descent without L1 regularization may lead to unexpected results and
is discouraged. Set l1_ratio > 0 to add L1 regularization.
  model = cd_fast.enet_coordinate_descent_gram(
/opt/conda/lib/python3.11/site-
packages/sklearn/linear_model/_coordinate_descent.py:614: ConvergenceWarning:
Objective did not converge. You might want to increase the number of iterations.
Duality gap: 4090.324406132146, tolerance: 0.8229000000000001
  model = cd_fast.enet_coordinate_descent_gram(
/opt/conda/lib/python3.11/site-
packages/sklearn/linear_model/_coordinate_descent.py:614: UserWarning:
Coordinate descent without L1 regularization may lead to unexpected results and
is discouraged. Set l1_ratio > 0 to add L1 regularization.
  model = cd_fast.enet_coordinate_descent_gram(
/opt/conda/lib/python3.11/site-
packages/sklearn/linear_model/_coordinate_descent.py:614: ConvergenceWarning:
Objective did not converge. You might want to increase the number of iterations.
Duality gap: 4085.0445219236904, tolerance: 0.8229000000000001
  model = cd_fast.enet_coordinate_descent_gram(
/opt/conda/lib/python3.11/site-
packages/sklearn/linear_model/_coordinate_descent.py:614: UserWarning:
Coordinate descent without L1 regularization may lead to unexpected results and
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  model = cd_fast.enet_coordinate_descent_gram(
/opt/conda/lib/python3.11/site-
packages/sklearn/linear_model/_coordinate_descent.py:614: ConvergenceWarning:
Objective did not converge. You might want to increase the number of iterations.
Duality gap: 4078.864783280014, tolerance: 0.8229000000000001
  model = cd_fast.enet_coordinate_descent_gram(
/opt/conda/lib/python3.11/site-
packages/sklearn/linear_model/_coordinate_descent.py:614: UserWarning:
Coordinate descent without L1 regularization may lead to unexpected results and
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  model = cd_fast.enet_coordinate_descent_gram(
/opt/conda/lib/python3.11/site-
packages/sklearn/linear_model/_coordinate_descent.py:614: ConvergenceWarning:
Objective did not converge. You might want to increase the number of iterations.
Duality gap: 4071.735456331201, tolerance: 0.8229000000000001
  model = cd_fast.enet_coordinate_descent_gram(
/opt/conda/lib/python3.11/site-
packages/sklearn/linear_model/_coordinate_descent.py:614: UserWarning:
Coordinate descent without L1 regularization may lead to unexpected results and
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```

```
  model = cd_fast.enet_coordinate_descent_gram(
/opt/conda/lib/python3.11/site-
packages/sklearn/linear_model/_coordinate_descent.py:614: ConvergenceWarning:
Objective did not converge. You might want to increase the number of iterations.
Duality gap: 4063.6432039917922, tolerance: 0.8229000000000001
  model = cd_fast.enet_coordinate_descent_gram(
/opt/conda/lib/python3.11/site-
packages/sklearn/linear_model/_coordinate_descent.py:614: UserWarning:
Coordinate descent without L1 regularization may lead to unexpected results and
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  model = cd_fast.enet_coordinate_descent_gram(
/opt/conda/lib/python3.11/site-
packages/sklearn/linear_model/_coordinate_descent.py:614: ConvergenceWarning:
Objective did not converge. You might want to increase the number of iterations.
Duality gap: 4054.6220680527904, tolerance: 0.8229000000000001
  model = cd_fast.enet_coordinate_descent_gram(
/opt/conda/lib/python3.11/site-
packages/sklearn/linear_model/_coordinate_descent.py:614: UserWarning:
Coordinate descent without L1 regularization may lead to unexpected results and
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  model = cd_fast.enet_coordinate_descent_gram(
/opt/conda/lib/python3.11/site-
packages/sklearn/linear_model/_coordinate_descent.py:614: ConvergenceWarning:
Objective did not converge. You might want to increase the number of iterations.
Duality gap: 4044.7615461377864, tolerance: 0.8229000000000001
  model = cd_fast.enet_coordinate_descent_gram(
/opt/conda/lib/python3.11/site-
packages/sklearn/linear_model/_coordinate_descent.py:614: UserWarning:
Coordinate descent without L1 regularization may lead to unexpected results and
is discouraged. Set l1_ratio > 0 to add L1 regularization.
  model = cd_fast.enet_coordinate_descent_gram(
/opt/conda/lib/python3.11/site-
packages/sklearn/linear_model/_coordinate_descent.py:614: ConvergenceWarning:
Objective did not converge. You might want to increase the number of iterations.
Duality gap: 4034.2094308932533, tolerance: 0.8229000000000001
  model = cd_fast.enet_coordinate_descent_gram(
/opt/conda/lib/python3.11/site-
packages/sklearn/linear_model/_coordinate_descent.py:614: UserWarning:
Coordinate descent without L1 regularization may lead to unexpected results and
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  model = cd_fast.enet_coordinate_descent_gram(
/opt/conda/lib/python3.11/site-
packages/sklearn/linear_model/_coordinate_descent.py:614: ConvergenceWarning:
Objective did not converge. You might want to increase the number of iterations.
Duality gap: 4023.167486401245, tolerance: 0.8229000000000001
  model = cd_fast.enet_coordinate_descent_gram(
/opt/conda/lib/python3.11/site-
packages/sklearn/linear_model/_coordinate_descent.py:614: UserWarning:
```

```
Coordinate descent without L1 regularization may lead to unexpected results and
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  model = cd_fast.enet_coordinate_descent_gram(
/opt/conda/lib/python3.11/site-
packages/sklearn/linear_model/_coordinate_descent.py:614: ConvergenceWarning:
Objective did not converge. You might want to increase the number of iterations.
Duality gap: 4011.8791331693474, tolerance: 0.8229000000000001
  model = cd_fast.enet_coordinate_descent_gram(
/opt/conda/lib/python3.11/site-
packages/sklearn/linear_model/_coordinate_descent.py:614: UserWarning:
Coordinate descent without L1 regularization may lead to unexpected results and
is discouraged. Set l1_ratio > 0 to add L1 regularization.
  model = cd_fast.enet_coordinate_descent_gram(
/opt/conda/lib/python3.11/site-
packages/sklearn/linear_model/_coordinate_descent.py:614: ConvergenceWarning:
Objective did not converge. You might want to increase the number of iterations.
Duality gap: 4000.6100187129796, tolerance: 0.8229000000000001
  model = cd_fast.enet_coordinate_descent_gram(
/opt/conda/lib/python3.11/site-
packages/sklearn/linear_model/_coordinate_descent.py:614: UserWarning:
Coordinate descent without L1 regularization may lead to unexpected results and
is discouraged. Set l1_ratio > 0 to add L1 regularization.
  model = cd_fast.enet_coordinate_descent_gram(
/opt/conda/lib/python3.11/site-
packages/sklearn/linear_model/_coordinate_descent.py:614: ConvergenceWarning:
Objective did not converge. You might want to increase the number of iterations.
Duality gap: 3989.624268194306, tolerance: 0.8229000000000001
  model = cd_fast.enet_coordinate_descent_gram(
/opt/conda/lib/python3.11/site-
packages/sklearn/linear_model/_coordinate_descent.py:614: UserWarning:
Coordinate descent without L1 regularization may lead to unexpected results and
is discouraged. Set l1_ratio > 0 to add L1 regularization.
  model = cd_fast.enet_coordinate_descent_gram(
/opt/conda/lib/python3.11/site-
packages/sklearn/linear_model/_coordinate_descent.py:614: ConvergenceWarning:
Objective did not converge. You might want to increase the number of iterations.
Duality gap: 3979.1606432524945, tolerance: 0.8229000000000001
  model = cd_fast.enet_coordinate_descent_gram(
/opt/conda/lib/python3.11/site-
packages/sklearn/linear_model/_coordinate_descent.py:614: UserWarning:
Coordinate descent without L1 regularization may lead to unexpected results and
is discouraged. Set l1_ratio > 0 to add L1 regularization.
  model = cd_fast.enet_coordinate_descent_gram(
/opt/conda/lib/python3.11/site-
packages/sklearn/linear_model/_coordinate_descent.py:614: ConvergenceWarning:
Objective did not converge. You might want to increase the number of iterations.
Duality gap: 3969.4130870716444, tolerance: 0.8229000000000001
  model = cd_fast.enet_coordinate_descent_gram(
```

```
/opt/conda/lib/python3.11/site-
packages/sklearn/linear_model/_coordinate_descent.py:614: UserWarning:
Coordinate descent without L1 regularization may lead to unexpected results and
is discouraged. Set l1_ratio > 0 to add L1 regularization.
  model = cd_fast.enet_coordinate_descent_gram(
/opt/conda/lib/python3.11/site-
packages/sklearn/linear_model/_coordinate_descent.py:614: ConvergenceWarning:
Objective did not converge. You might want to increase the number of iterations.
Duality gap: 3960.51895098408, tolerance: 0.8229000000000001
  model = cd_fast.enet_coordinate_descent_gram(
/opt/conda/lib/python3.11/site-
packages/sklearn/linear_model/_coordinate_descent.py:614: UserWarning:
Coordinate descent without L1 regularization may lead to unexpected results and
is discouraged. Set l1_ratio > 0 to add L1 regularization.
  model = cd_fast.enet_coordinate_descent_gram(
/opt/conda/lib/python3.11/site-
packages/sklearn/linear_model/_coordinate_descent.py:614: ConvergenceWarning:
Objective did not converge. You might want to increase the number of iterations.
Duality gap: 3952.5560314023405, tolerance: 0.8229000000000001
  model = cd_fast.enet_coordinate_descent_gram(
```

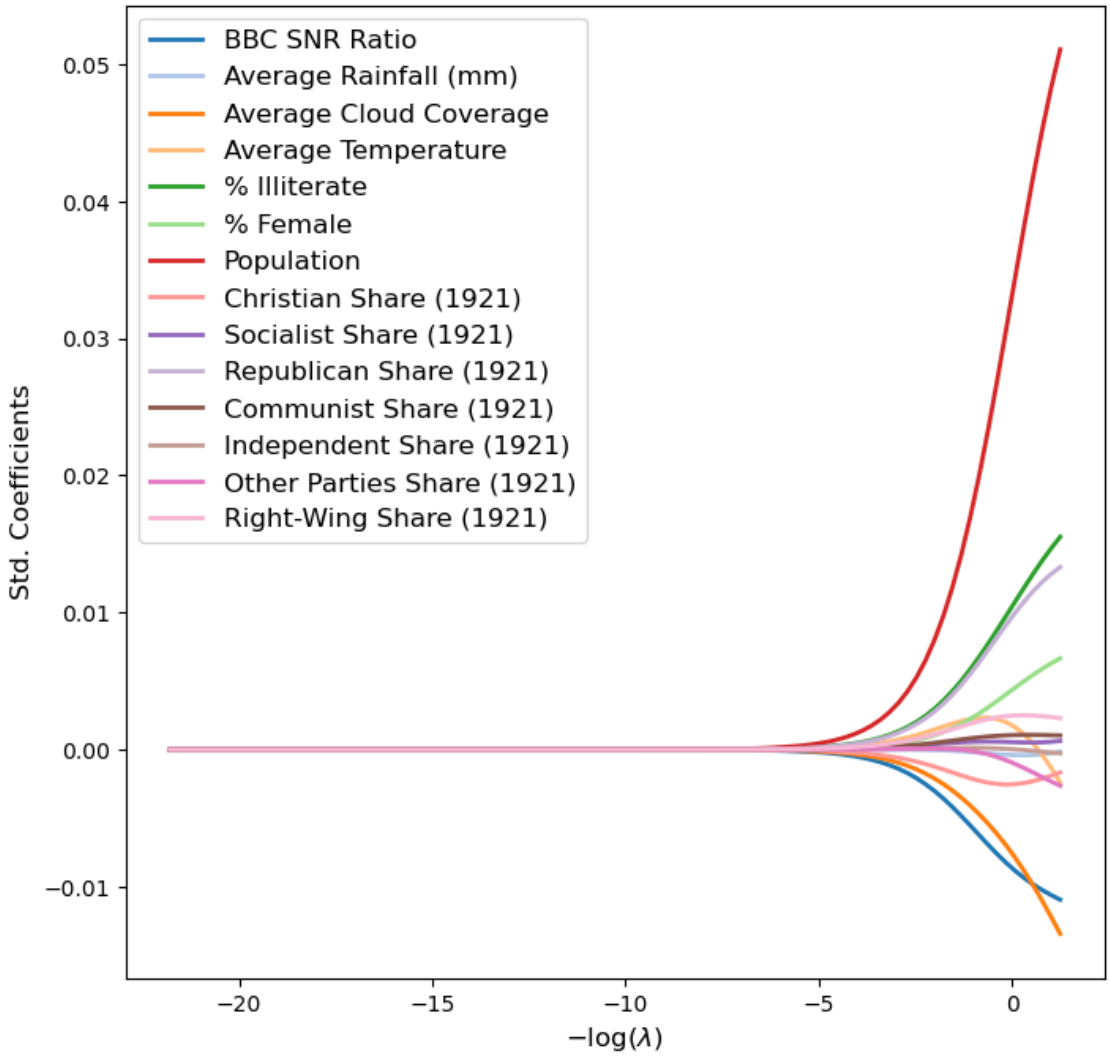
[28]:
```
ridge_reg_df = pd.DataFrame(ridge_reg.T,
                            columns=expl_mf.columns,
                            index=-np.log( 10**np.linspace(9, -1, 100) / dep.
 ↪std()))
ridge_reg_df.index.name = 'negative log(lambda)'

ridge_reg_df.rename(columns=graph_names_1921, inplace=True)

fig, lbls = subplots(figsize=(8,8))
colormap = get_cmap("tab20")
for i, column in enumerate(ridge_reg_df.columns):
    ridge_reg_df[column].plot(ax=lbls, color=colormap(i % 20), linewidth=2,␣
 ↪label=column)

lbls.set_xlabel('$-\log(\lambda)$', fontsize=12)
lbls.set_ylabel('Std. Coefficients', fontsize=12)
lbls.legend(loc='upper left', fontsize=12);
```

```
/tmp/ipykernel_102/2386564866.py:9: MatplotlibDeprecationWarning: The get_cmap
function was deprecated in Matplotlib 3.7 and will be removed two minor releases
later. Use ``matplotlib.colormaps[name]`` or
``matplotlib.colormaps.get_cmap(obj)`` instead.
  colormap = get_cmap("tab20")
```



[29]:
```
cv_model = Pipeline(steps=[('scaler', StandardScaler(with_mean=True, ␣
↪with_std=True)),
                           ('ridge', skl.ElasticNet(alpha=reg_lambda[50],␣
↪l1_ratio=0))])
cv_model.fit(expl, dep)
cv_fitted = skm.GridSearchCV(cv_model,
                        {'ridge__alpha': reg_lambda},
                        cv=skm.ShuffleSplit(n_splits=3,
                        test_size=0.25),
                        scoring='neg_mean_squared_error')
cv_fitted.fit(expl, dep)
cv_fitted.best_params_['ridge__alpha']
cv_fitted.best_estimator_
```

```
/opt/conda/lib/python3.11/site-
packages/sklearn/linear_model/_coordinate_descent.py:628: ConvergenceWarning:
Objective did not converge. You might want to increase the number of iterations,
check the scale of the features or consider increasing regularisation. Duality
gap: 4.023e+03, tolerance: 8.045e-01 Linear regression models with null weight
for the l1 regularization term are more efficiently fitted using one of the
solvers implemented in sklearn.linear_model.Ridge/RidgeCV instead.
  model = cd_fast.enet_coordinate_descent(
/opt/conda/lib/python3.11/site-
packages/sklearn/linear_model/_coordinate_descent.py:628: ConvergenceWarning:
Objective did not converge. You might want to increase the number of iterations,
check the scale of the features or consider increasing regularisation. Duality
gap: 2.938e+03, tolerance: 5.876e-01 Linear regression models with null weight
for the l1 regularization term are more efficiently fitted using one of the
solvers implemented in sklearn.linear_model.Ridge/RidgeCV instead.
  model = cd_fast.enet_coordinate_descent(
/opt/conda/lib/python3.11/site-
packages/sklearn/linear_model/_coordinate_descent.py:628: ConvergenceWarning:
Objective did not converge. You might want to increase the number of iterations,
check the scale of the features or consider increasing regularisation. Duality
gap: 3.124e+03, tolerance: 6.248e-01 Linear regression models with null weight
for the l1 regularization term are more efficiently fitted using one of the
solvers implemented in sklearn.linear_model.Ridge/RidgeCV instead.
  model = cd_fast.enet_coordinate_descent(
/opt/conda/lib/python3.11/site-
packages/sklearn/linear_model/_coordinate_descent.py:628: ConvergenceWarning:
Objective did not converge. You might want to increase the number of iterations,
check the scale of the features or consider increasing regularisation. Duality
gap: 2.983e+03, tolerance: 5.966e-01 Linear regression models with null weight
for the l1 regularization term are more efficiently fitted using one of the
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/opt/conda/lib/python3.11/site-
packages/sklearn/linear_model/_coordinate_descent.py:628: ConvergenceWarning:
Objective did not converge. You might want to increase the number of iterations,
check the scale of the features or consider increasing regularisation. Duality
gap: 2.902e+03, tolerance: 5.876e-01 Linear regression models with null weight
for the l1 regularization term are more efficiently fitted using one of the
solvers implemented in sklearn.linear_model.Ridge/RidgeCV instead.
  model = cd_fast.enet_coordinate_descent(
/opt/conda/lib/python3.11/site-
packages/sklearn/linear_model/_coordinate_descent.py:628: ConvergenceWarning:
Objective did not converge. You might want to increase the number of iterations,
check the scale of the features or consider increasing regularisation. Duality
gap: 3.088e+03, tolerance: 6.248e-01 Linear regression models with null weight
for the l1 regularization term are more efficiently fitted using one of the
solvers implemented in sklearn.linear_model.Ridge/RidgeCV instead.
  model = cd_fast.enet_coordinate_descent(
/opt/conda/lib/python3.11/site-
packages/sklearn/linear_model/_coordinate_descent.py:628: ConvergenceWarning:
Objective did not converge. You might want to increase the number of iterations,
check the scale of the features or consider increasing regularisation. Duality
gap: 2.946e+03, tolerance: 5.966e-01 Linear regression models with null weight
for the l1 regularization term are more efficiently fitted using one of the
solvers implemented in sklearn.linear_model.Ridge/RidgeCV instead.
  model = cd_fast.enet_coordinate_descent(
/opt/conda/lib/python3.11/site-
packages/sklearn/linear_model/_coordinate_descent.py:628: ConvergenceWarning:
Objective did not converge. You might want to increase the number of iterations,
check the scale of the features or consider increasing regularisation. Duality
gap: 2.896e+03, tolerance: 5.876e-01 Linear regression models with null weight
for the l1 regularization term are more efficiently fitted using one of the
solvers implemented in sklearn.linear_model.Ridge/RidgeCV instead.
  model = cd_fast.enet_coordinate_descent(
/opt/conda/lib/python3.11/site-
packages/sklearn/linear_model/_coordinate_descent.py:628: ConvergenceWarning:
Objective did not converge. You might want to increase the number of iterations,
check the scale of the features or consider increasing regularisation. Duality
gap: 3.082e+03, tolerance: 6.248e-01 Linear regression models with null weight
for the l1 regularization term are more efficiently fitted using one of the
solvers implemented in sklearn.linear_model.Ridge/RidgeCV instead.
  model = cd_fast.enet_coordinate_descent(
```

```
/opt/conda/lib/python3.11/site-
packages/sklearn/linear_model/_coordinate_descent.py:628: ConvergenceWarning:
Objective did not converge. You might want to increase the number of iterations,
check the scale of the features or consider increasing regularisation. Duality
gap: 2.939e+03, tolerance: 5.966e-01 Linear regression models with null weight
for the l1 regularization term are more efficiently fitted using one of the
solvers implemented in sklearn.linear_model.Ridge/RidgeCV instead.
  model = cd_fast.enet_coordinate_descent(
/opt/conda/lib/python3.11/site-
packages/sklearn/linear_model/_coordinate_descent.py:628: ConvergenceWarning:
Objective did not converge. You might want to increase the number of iterations,
check the scale of the features or consider increasing regularisation. Duality
gap: 2.889e+03, tolerance: 5.876e-01 Linear regression models with null weight
for the l1 regularization term are more efficiently fitted using one of the
solvers implemented in sklearn.linear_model.Ridge/RidgeCV instead.
  model = cd_fast.enet_coordinate_descent(
/opt/conda/lib/python3.11/site-
packages/sklearn/linear_model/_coordinate_descent.py:628: ConvergenceWarning:
Objective did not converge. You might want to increase the number of iterations,
check the scale of the features or consider increasing regularisation. Duality
gap: 3.075e+03, tolerance: 6.248e-01 Linear regression models with null weight
for the l1 regularization term are more efficiently fitted using one of the
solvers implemented in sklearn.linear_model.Ridge/RidgeCV instead.
  model = cd_fast.enet_coordinate_descent(
/opt/conda/lib/python3.11/site-
packages/sklearn/linear_model/_coordinate_descent.py:628: ConvergenceWarning:
Objective did not converge. You might want to increase the number of iterations,
check the scale of the features or consider increasing regularisation. Duality
gap: 2.932e+03, tolerance: 5.966e-01 Linear regression models with null weight
for the l1 regularization term are more efficiently fitted using one of the
solvers implemented in sklearn.linear_model.Ridge/RidgeCV instead.
  model = cd_fast.enet_coordinate_descent(
/opt/conda/lib/python3.11/site-
packages/sklearn/linear_model/_coordinate_descent.py:628: ConvergenceWarning:
Objective did not converge. You might want to increase the number of iterations,
check the scale of the features or consider increasing regularisation. Duality
gap: 2.882e+03, tolerance: 5.876e-01 Linear regression models with null weight
for the l1 regularization term are more efficiently fitted using one of the
solvers implemented in sklearn.linear_model.Ridge/RidgeCV instead.
  model = cd_fast.enet_coordinate_descent(
/opt/conda/lib/python3.11/site-
packages/sklearn/linear_model/_coordinate_descent.py:628: ConvergenceWarning:
Objective did not converge. You might want to increase the number of iterations,
check the scale of the features or consider increasing regularisation. Duality
gap: 3.067e+03, tolerance: 6.248e-01 Linear regression models with null weight
for the l1 regularization term are more efficiently fitted using one of the
solvers implemented in sklearn.linear_model.Ridge/RidgeCV instead.
  model = cd_fast.enet_coordinate_descent(
```

```
/opt/conda/lib/python3.11/site-
packages/sklearn/linear_model/_coordinate_descent.py:628: ConvergenceWarning:
Objective did not converge. You might want to increase the number of iterations,
check the scale of the features or consider increasing regularisation. Duality
gap: 2.924e+03, tolerance: 5.966e-01 Linear regression models with null weight
for the l1 regularization term are more efficiently fitted using one of the
solvers implemented in sklearn.linear_model.Ridge/RidgeCV instead.
  model = cd_fast.enet_coordinate_descent(
/opt/conda/lib/python3.11/site-
packages/sklearn/linear_model/_coordinate_descent.py:628: ConvergenceWarning:
Objective did not converge. You might want to increase the number of iterations,
check the scale of the features or consider increasing regularisation. Duality
gap: 2.874e+03, tolerance: 5.876e-01 Linear regression models with null weight
for the l1 regularization term are more efficiently fitted using one of the
solvers implemented in sklearn.linear_model.Ridge/RidgeCV instead.
  model = cd_fast.enet_coordinate_descent(
/opt/conda/lib/python3.11/site-
packages/sklearn/linear_model/_coordinate_descent.py:628: ConvergenceWarning:
Objective did not converge. You might want to increase the number of iterations,
check the scale of the features or consider increasing regularisation. Duality
gap: 3.059e+03, tolerance: 6.248e-01 Linear regression models with null weight
for the l1 regularization term are more efficiently fitted using one of the
solvers implemented in sklearn.linear_model.Ridge/RidgeCV instead.
  model = cd_fast.enet_coordinate_descent(
/opt/conda/lib/python3.11/site-
packages/sklearn/linear_model/_coordinate_descent.py:628: ConvergenceWarning:
Objective did not converge. You might want to increase the number of iterations,
check the scale of the features or consider increasing regularisation. Duality
gap: 2.916e+03, tolerance: 5.966e-01 Linear regression models with null weight
for the l1 regularization term are more efficiently fitted using one of the
solvers implemented in sklearn.linear_model.Ridge/RidgeCV instead.
  model = cd_fast.enet_coordinate_descent(
/opt/conda/lib/python3.11/site-
packages/sklearn/linear_model/_coordinate_descent.py:628: ConvergenceWarning:
Objective did not converge. You might want to increase the number of iterations,
check the scale of the features or consider increasing regularisation. Duality
gap: 2.866e+03, tolerance: 5.876e-01 Linear regression models with null weight
for the l1 regularization term are more efficiently fitted using one of the
solvers implemented in sklearn.linear_model.Ridge/RidgeCV instead.
  model = cd_fast.enet_coordinate_descent(
/opt/conda/lib/python3.11/site-
packages/sklearn/linear_model/_coordinate_descent.py:628: ConvergenceWarning:
Objective did not converge. You might want to increase the number of iterations,
check the scale of the features or consider increasing regularisation. Duality
gap: 3.051e+03, tolerance: 6.248e-01 Linear regression models with null weight
for the l1 regularization term are more efficiently fitted using one of the
solvers implemented in sklearn.linear_model.Ridge/RidgeCV instead.
  model = cd_fast.enet_coordinate_descent(
```

```
/opt/conda/lib/python3.11/site-
packages/sklearn/linear_model/_coordinate_descent.py:628: ConvergenceWarning:
Objective did not converge. You might want to increase the number of iterations,
check the scale of the features or consider increasing regularisation. Duality
gap: 2.908e+03, tolerance: 5.966e-01 Linear regression models with null weight
for the l1 regularization term are more efficiently fitted using one of the
solvers implemented in sklearn.linear_model.Ridge/RidgeCV instead.
  model = cd_fast.enet_coordinate_descent(
/opt/conda/lib/python3.11/site-
packages/sklearn/linear_model/_coordinate_descent.py:628: ConvergenceWarning:
Objective did not converge. You might want to increase the number of iterations,
check the scale of the features or consider increasing regularisation. Duality
gap: 2.858e+03, tolerance: 5.876e-01 Linear regression models with null weight
for the l1 regularization term are more efficiently fitted using one of the
solvers implemented in sklearn.linear_model.Ridge/RidgeCV instead.
  model = cd_fast.enet_coordinate_descent(
/opt/conda/lib/python3.11/site-
packages/sklearn/linear_model/_coordinate_descent.py:628: ConvergenceWarning:
Objective did not converge. You might want to increase the number of iterations,
check the scale of the features or consider increasing regularisation. Duality
gap: 3.043e+03, tolerance: 6.248e-01 Linear regression models with null weight
for the l1 regularization term are more efficiently fitted using one of the
solvers implemented in sklearn.linear_model.Ridge/RidgeCV instead.
  model = cd_fast.enet_coordinate_descent(
/opt/conda/lib/python3.11/site-
packages/sklearn/linear_model/_coordinate_descent.py:628: ConvergenceWarning:
Objective did not converge. You might want to increase the number of iterations,
check the scale of the features or consider increasing regularisation. Duality
gap: 2.900e+03, tolerance: 5.966e-01 Linear regression models with null weight
for the l1 regularization term are more efficiently fitted using one of the
solvers implemented in sklearn.linear_model.Ridge/RidgeCV instead.
  model = cd_fast.enet_coordinate_descent(
/opt/conda/lib/python3.11/site-
packages/sklearn/linear_model/_coordinate_descent.py:628: ConvergenceWarning:
Objective did not converge. You might want to increase the number of iterations,
check the scale of the features or consider increasing regularisation. Duality
gap: 2.851e+03, tolerance: 5.876e-01 Linear regression models with null weight
for the l1 regularization term are more efficiently fitted using one of the
solvers implemented in sklearn.linear_model.Ridge/RidgeCV instead.
  model = cd_fast.enet_coordinate_descent(
/opt/conda/lib/python3.11/site-
packages/sklearn/linear_model/_coordinate_descent.py:628: ConvergenceWarning:
Objective did not converge. You might want to increase the number of iterations,
check the scale of the features or consider increasing regularisation. Duality
gap: 3.035e+03, tolerance: 6.248e-01 Linear regression models with null weight
for the l1 regularization term are more efficiently fitted using one of the
solvers implemented in sklearn.linear_model.Ridge/RidgeCV instead.
  model = cd_fast.enet_coordinate_descent(
```

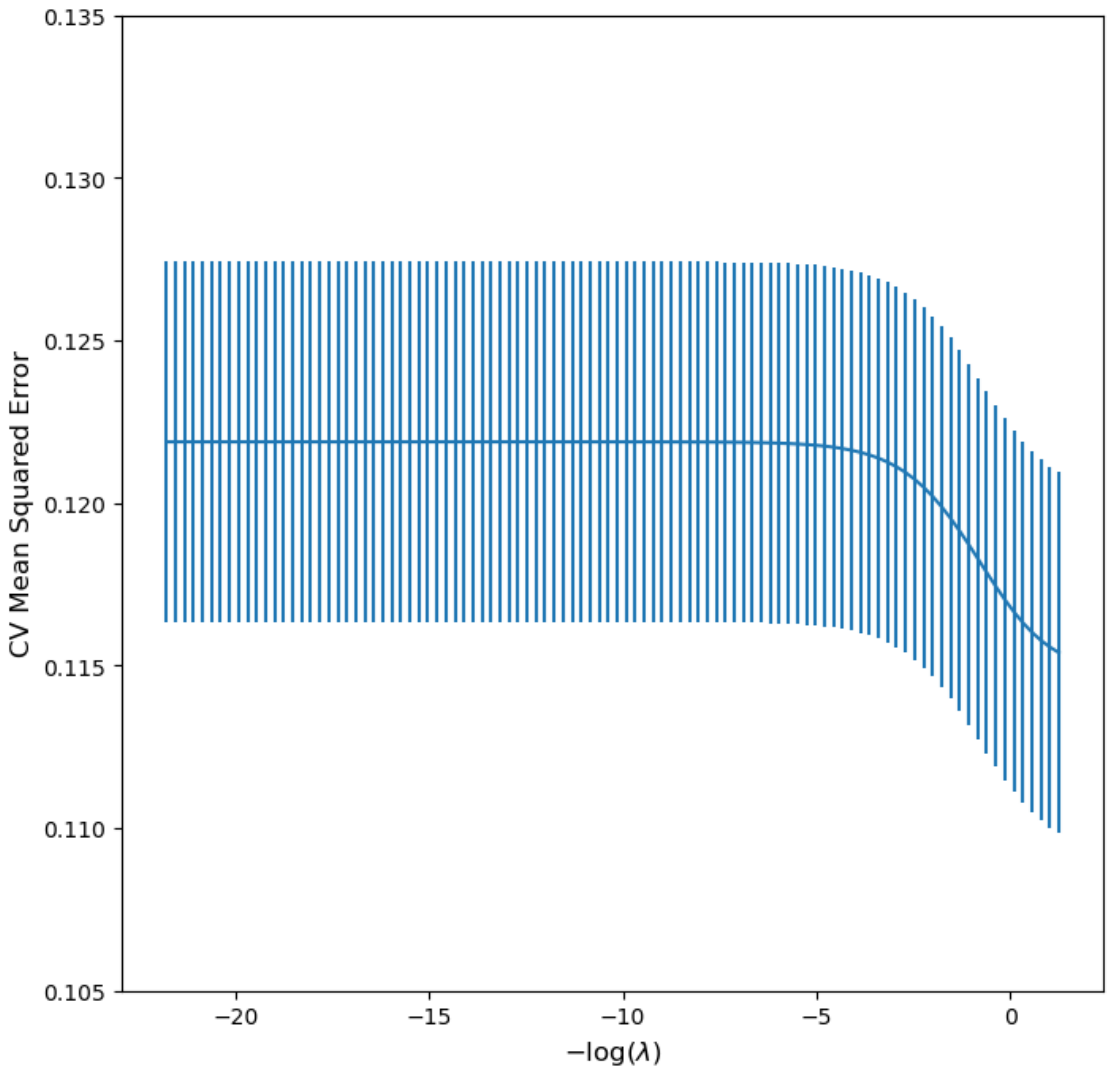
```
/opt/conda/lib/python3.11/site-
packages/sklearn/linear_model/_coordinate_descent.py:628: ConvergenceWarning:
Objective did not converge. You might want to increase the number of iterations,
check the scale of the features or consider increasing regularisation. Duality
gap: 2.892e+03, tolerance: 5.966e-01 Linear regression models with null weight
for the l1 regularization term are more efficiently fitted using one of the
solvers implemented in sklearn.linear_model.Ridge/RidgeCV instead.
  model = cd_fast.enet_coordinate_descent(
/opt/conda/lib/python3.11/site-
packages/sklearn/linear_model/_coordinate_descent.py:628: ConvergenceWarning:
Objective did not converge. You might want to increase the number of iterations,
check the scale of the features or consider increasing regularisation. Duality
gap: 2.843e+03, tolerance: 5.876e-01 Linear regression models with null weight
for the l1 regularization term are more efficiently fitted using one of the
solvers implemented in sklearn.linear_model.Ridge/RidgeCV instead.
  model = cd_fast.enet_coordinate_descent(
/opt/conda/lib/python3.11/site-
packages/sklearn/linear_model/_coordinate_descent.py:628: ConvergenceWarning:
Objective did not converge. You might want to increase the number of iterations,
check the scale of the features or consider increasing regularisation. Duality
gap: 3.028e+03, tolerance: 6.248e-01 Linear regression models with null weight
for the l1 regularization term are more efficiently fitted using one of the
solvers implemented in sklearn.linear_model.Ridge/RidgeCV instead.
  model = cd_fast.enet_coordinate_descent(
/opt/conda/lib/python3.11/site-
packages/sklearn/linear_model/_coordinate_descent.py:628: ConvergenceWarning:
Objective did not converge. You might want to increase the number of iterations,
check the scale of the features or consider increasing regularisation. Duality
gap: 2.885e+03, tolerance: 5.966e-01 Linear regression models with null weight
for the l1 regularization term are more efficiently fitted using one of the
solvers implemented in sklearn.linear_model.Ridge/RidgeCV instead.
  model = cd_fast.enet_coordinate_descent(
/opt/conda/lib/python3.11/site-
packages/sklearn/linear_model/_coordinate_descent.py:628: ConvergenceWarning:
Objective did not converge. You might want to increase the number of iterations,
check the scale of the features or consider increasing regularisation. Duality
gap: 2.837e+03, tolerance: 5.876e-01 Linear regression models with null weight
for the l1 regularization term are more efficiently fitted using one of the
solvers implemented in sklearn.linear_model.Ridge/RidgeCV instead.
  model = cd_fast.enet_coordinate_descent(
/opt/conda/lib/python3.11/site-
packages/sklearn/linear_model/_coordinate_descent.py:628: ConvergenceWarning:
Objective did not converge. You might want to increase the number of iterations,
check the scale of the features or consider increasing regularisation. Duality
gap: 3.021e+03, tolerance: 6.248e-01 Linear regression models with null weight
for the l1 regularization term are more efficiently fitted using one of the
solvers implemented in sklearn.linear_model.Ridge/RidgeCV instead.
  model = cd_fast.enet_coordinate_descent(
```

```
/opt/conda/lib/python3.11/site-
packages/sklearn/linear_model/_coordinate_descent.py:628: ConvergenceWarning:
Objective did not converge. You might want to increase the number of iterations,
check the scale of the features or consider increasing regularisation. Duality
gap: 2.878e+03, tolerance: 5.966e-01 Linear regression models with null weight
for the l1 regularization term are more efficiently fitted using one of the
solvers implemented in sklearn.linear_model.Ridge/RidgeCV instead.
  model = cd_fast.enet_coordinate_descent(
/opt/conda/lib/python3.11/site-
packages/sklearn/linear_model/_coordinate_descent.py:628: ConvergenceWarning:
Objective did not converge. You might want to increase the number of iterations,
check the scale of the features or consider increasing regularisation. Duality
gap: 2.831e+03, tolerance: 5.876e-01 Linear regression models with null weight
for the l1 regularization term are more efficiently fitted using one of the
solvers implemented in sklearn.linear_model.Ridge/RidgeCV instead.
  model = cd_fast.enet_coordinate_descent(
/opt/conda/lib/python3.11/site-
packages/sklearn/linear_model/_coordinate_descent.py:628: ConvergenceWarning:
Objective did not converge. You might want to increase the number of iterations,
check the scale of the features or consider increasing regularisation. Duality
gap: 3.015e+03, tolerance: 6.248e-01 Linear regression models with null weight
for the l1 regularization term are more efficiently fitted using one of the
solvers implemented in sklearn.linear_model.Ridge/RidgeCV instead.
  model = cd_fast.enet_coordinate_descent(
/opt/conda/lib/python3.11/site-
packages/sklearn/linear_model/_coordinate_descent.py:628: ConvergenceWarning:
Objective did not converge. You might want to increase the number of iterations,
check the scale of the features or consider increasing regularisation. Duality
gap: 2.871e+03, tolerance: 5.966e-01 Linear regression models with null weight
for the l1 regularization term are more efficiently fitted using one of the
solvers implemented in sklearn.linear_model.Ridge/RidgeCV instead.
  model = cd_fast.enet_coordinate_descent(
/opt/conda/lib/python3.11/site-
packages/sklearn/linear_model/_coordinate_descent.py:628: ConvergenceWarning:
Objective did not converge. You might want to increase the number of iterations,
check the scale of the features or consider increasing regularisation. Duality
gap: 2.825e+03, tolerance: 5.876e-01 Linear regression models with null weight
for the l1 regularization term are more efficiently fitted using one of the
solvers implemented in sklearn.linear_model.Ridge/RidgeCV instead.
  model = cd_fast.enet_coordinate_descent(
/opt/conda/lib/python3.11/site-
packages/sklearn/linear_model/_coordinate_descent.py:628: ConvergenceWarning:
Objective did not converge. You might want to increase the number of iterations,
check the scale of the features or consider increasing regularisation. Duality
gap: 3.009e+03, tolerance: 6.248e-01 Linear regression models with null weight
for the l1 regularization term are more efficiently fitted using one of the
solvers implemented in sklearn.linear_model.Ridge/RidgeCV instead.
  model = cd_fast.enet_coordinate_descent(
```

```
/opt/conda/lib/python3.11/site-
packages/sklearn/linear_model/_coordinate_descent.py:628: ConvergenceWarning:
Objective did not converge. You might want to increase the number of iterations,
check the scale of the features or consider increasing regularisation. Duality
gap: 2.866e+03, tolerance: 5.966e-01 Linear regression models with null weight
for the l1 regularization term are more efficiently fitted using one of the
solvers implemented in sklearn.linear_model.Ridge/RidgeCV instead.
  model = cd_fast.enet_coordinate_descent(
/opt/conda/lib/python3.11/site-
packages/sklearn/linear_model/_coordinate_descent.py:628: ConvergenceWarning:
Objective did not converge. You might want to increase the number of iterations,
check the scale of the features or consider increasing regularisation. Duality
gap: 3.861e+03, tolerance: 8.045e-01 Linear regression models with null weight
for the l1 regularization term are more efficiently fitted using one of the
solvers implemented in sklearn.linear_model.Ridge/RidgeCV instead.
  model = cd_fast.enet_coordinate_descent(
```

[29]:
```
Pipeline(steps=[('scaler', StandardScaler()),
                ('ridge', ElasticNet(alpha=0.28672282488638, l1_ratio=0))])
```

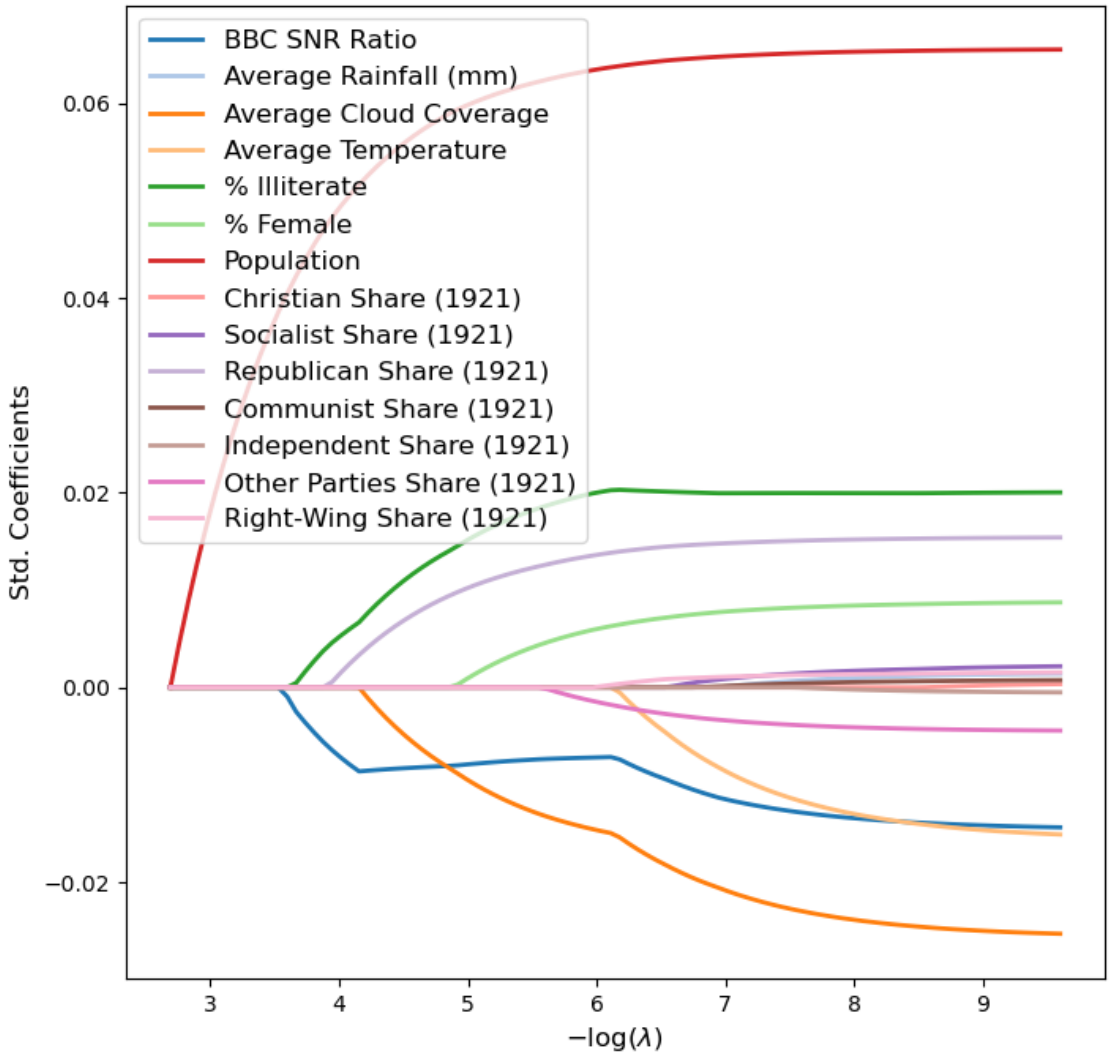
[31]:
```
ridge_fig, lbls = subplots(figsize=(8,8))
lbls.errorbar(-np.log(reg_lambda),
            -cv_fitted.cv_results_['mean_test_score'],
            yerr=cv_fitted.cv_results_['std_test_score'] / np.sqrt(3))
lbls.set_ylim([0.105,0.135])
lbls.set_xlabel('$-\log(\lambda)$', fontsize=12)
lbls.set_ylabel('CV Mean Squared Error', fontsize=12);
```



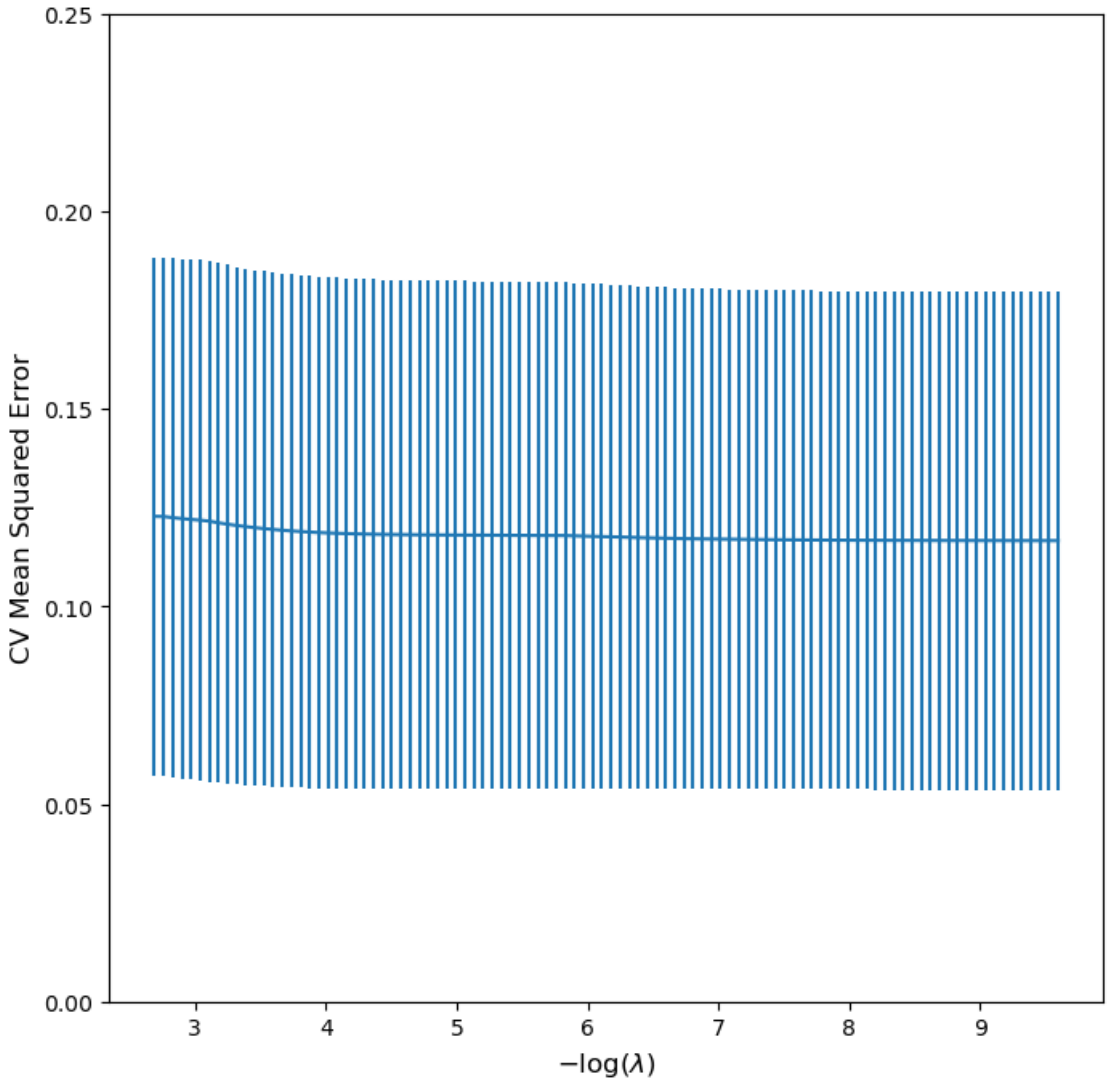
[32]:
```
lasso_lambdas, lasso_reg = skl.Lasso.path(expl_scaled,
                                          dep,
                                          l1_ratio=1,
                                          n_alphas=100)[:2]

lasso_reg_df = pd.DataFrame(lasso_reg.T,
                            columns=expl_mf.columns,
                            index=-np.log(lasso_lambdas))
lasso_reg_df.rename(columns = graph_names_1921, inplace = True)

fig, lbls = subplots(figsize=(8,8))
colormap = get_cmap("tab20")
for i, column in enumerate(lasso_reg_df.columns):
```

```
    lasso_reg_df[column].plot(ax=lbls, color=colormap(i % 20), linewidth=2,␣
 ↪label=column)

lbls.set_xlabel('$-\log(\lambda)$', fontsize=12)
lbls.set_ylabel('Std. Coefficients', fontsize=12)
lbls.legend(loc='upper left', fontsize=12);
```

```
/tmp/ipykernel_102/1322633521.py:12: MatplotlibDeprecationWarning: The get_cmap
function was deprecated in Matplotlib 3.7 and will be removed two minor releases
later. Use ``matplotlib.colormaps[name]`` or
``matplotlib.colormaps.get_cmap(obj)`` instead.
  colormap = get_cmap("tab20")
```

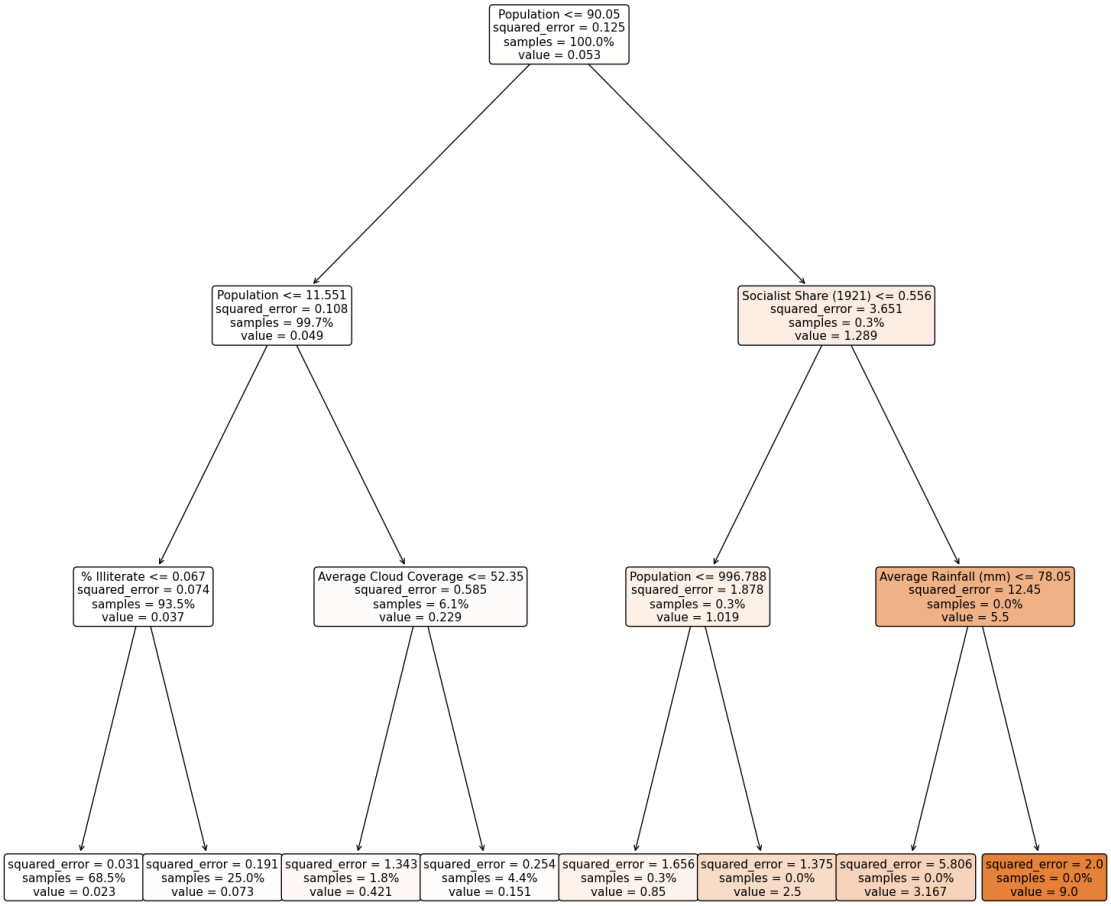


[33]:
```
cv_model = Pipeline(steps=[('scaler', StandardScaler(with_mean=True, ␣
 ↪with_std=True)),
                           ('lasso', skl.ElasticNetCV(n_alphas=100,
                             l1_ratio=1,
                             cv=3))])
cv_model.fit(expl, dep)
cv_fitted = cv_model.named_steps['lasso']
lasso_fig, lbls = subplots(figsize=(8,8))
lbls.errorbar(-np.log(cv_fitted.alphas_),
              cv_fitted.mse_path_.mean(1),
              yerr=cv_fitted.mse_path_.std(1) / np.sqrt(3))
lbls.set_ylim([0.0,0.25])
lbls.set_xlabel('$-\log(\lambda)$', fontsize=12)
lbls.set_ylabel('CV Mean Squared Error', fontsize=12);
```



[Model 5] Tree-Based Model

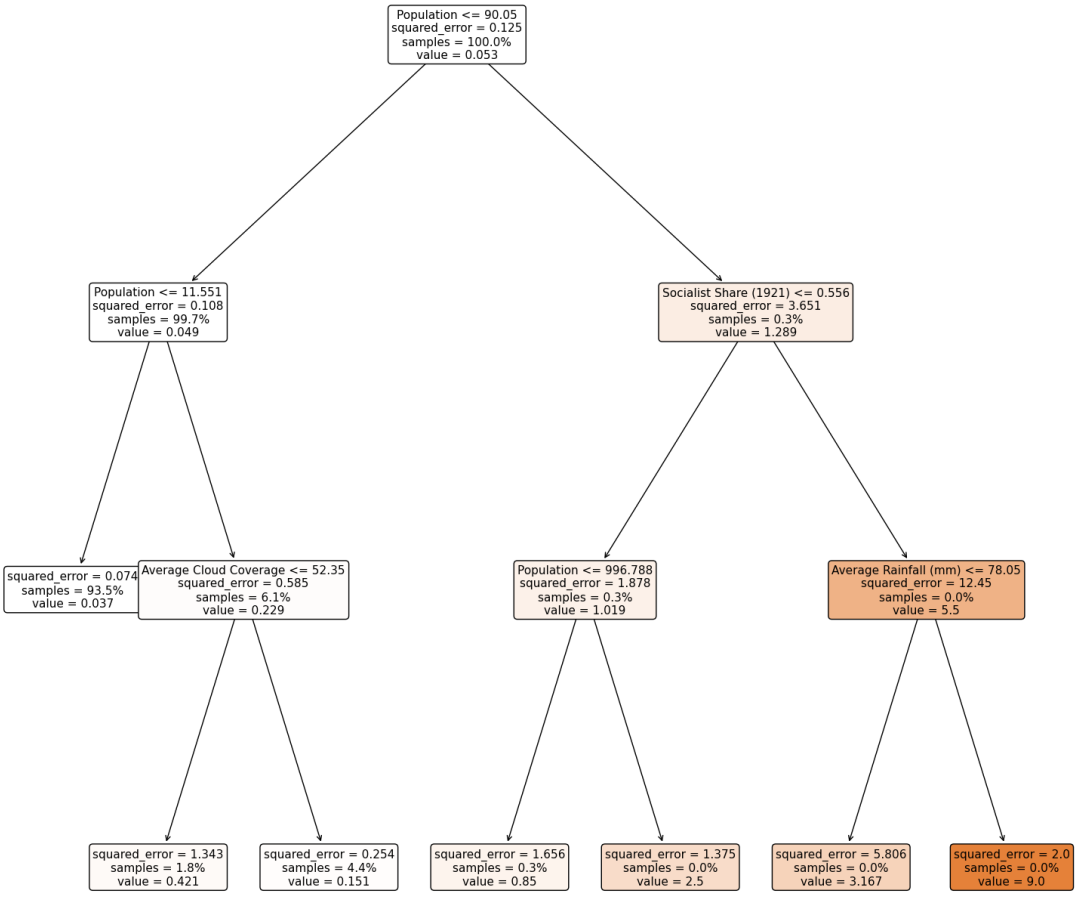
[34]:
```
tree_2021 = reg_data.loc[:, reg_data.columns.str.contains('|'.
 ↪join(controls_1921 + ['violence_episode_total']))]
tree_model = MS(tree_2021.columns.drop('violence_episode_total'),␣
 ↪intercept=False)
expl_data = tree_model.fit_transform(reg_data)
expl = np.asarray(expl_data)

(expl_train, expl_test, dep_train, dep_test) = skm.train_test_split(expl_data,
                                tree_2021['violence_episode_total'],
                                test_size=0.25, random_state = random_st)
base_tree = DTR(max_depth=3, random_state = random_st)
base_tree.fit(expl_train, dep_train)

tree_fig, lbls = plt.subplots(figsize=(15, 15))
lbls_name = [graph_names_1921.get(name, name) for name in expl_data.columns]
plot_tree(base_tree,
          feature_names=lbls_name,
          filled=True,
          rounded=True,
          proportion=True,
          fontsize=11);
plt.tight_layout()
```



[35]:
```
prune_tree = base_tree.cost_complexity_pruning_path(expl_train, dep_train)
prune_model = skm.GridSearchCV(base_tree,
                        {'ccp_alpha': prune_tree.ccp_alphas},
                        refit=True,
                        cv= skm.KFold(5,
                            shuffle=True,
                            random_state = random_st),
                        scoring='neg_mean_squared_error')
prune_fitted = prune_model.fit(expl_train, dep_train)
pruned_tree = prune_fitted.best_estimator_
np.mean((dep_test - pruned_tree.predict(expl_test))**2)
```

[35]:
0.1066628608284

[36]:
```
lbls = subplots(figsize=(15,15))[1]
plot_tree(prune_fitted.best_estimator_,
          feature_names=lbls_name,
          filled=True,
          rounded=True,
          proportion=True,
          fontsize=11);
plt.tight_layout()
```

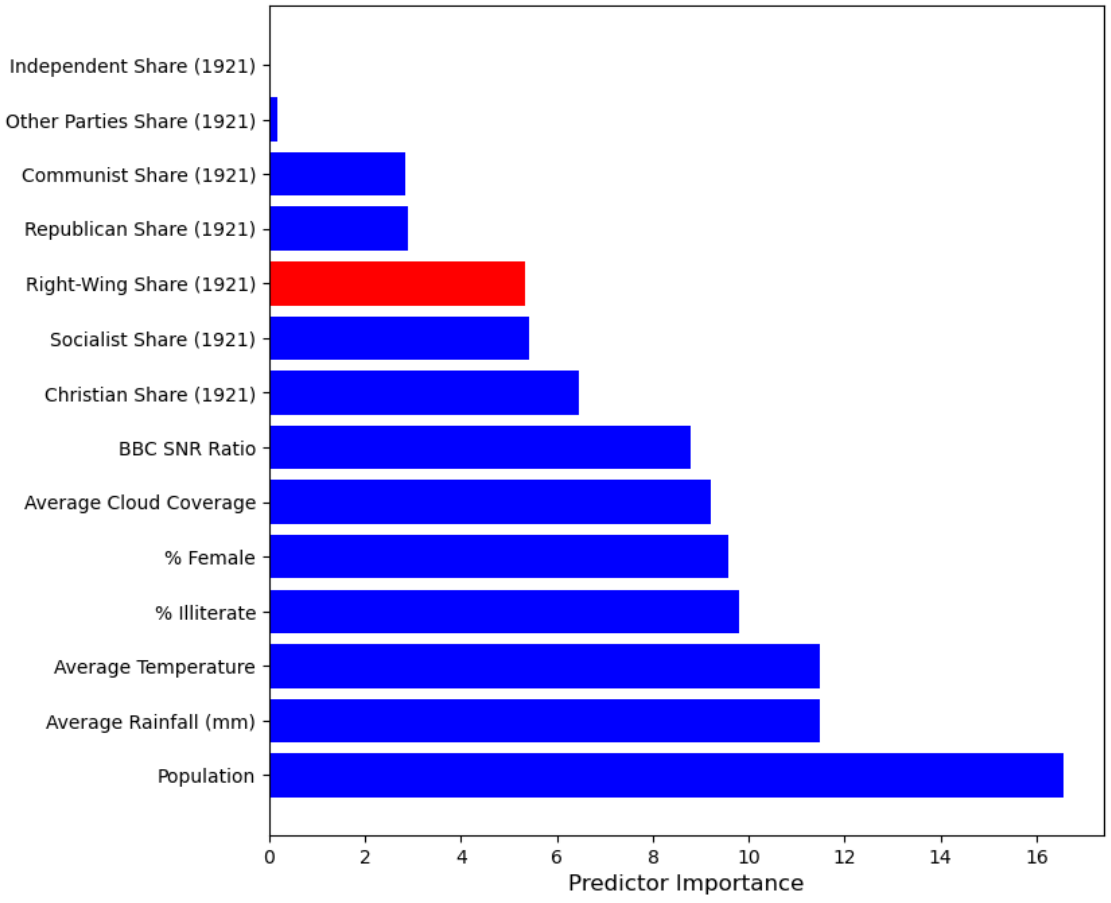


[37]:
```
rf_expl = tree_2021.drop(['violence_episode_total'], axis = 1)
rf_dep = tree_2021['violence_episode_total']
random_f = RandomForestRegressor(max_features=5, random_state=random_st).
 ↪fit(rf_expl, rf_dep)
```

```
rf_pr = random_f.predict(rf_expl)
mean_squared_error(rf_dep, rf_pr)
```

[37]:
0.0140829183108813

[38]:
```
rf_imp = pd.DataFrame({'Predictor Importance':random_f.
 ↪feature_importances_*100}, index=rf_expl.columns)
rf_imp.index = rf_imp.index.map(graph_names_1921)
rf_imp = rf_imp.sort_values('Predictor Importance', axis=0, ascending=False)
lbl_col = ['red' if l == 'Right-Wing Share (1921)' else 'blue' for l in rf_imp.
 ↪index]

rf_imp_pl, lbls = plt.subplots(figsize=(8, 8))
rf_score = lbls.barh(rf_imp.index, rf_imp['Predictor Importance'],␣
 ↪color=lbl_col)

plt.xlabel('Predictor Importance', fontsize = 12)
plt.gca().legend_ = None
```

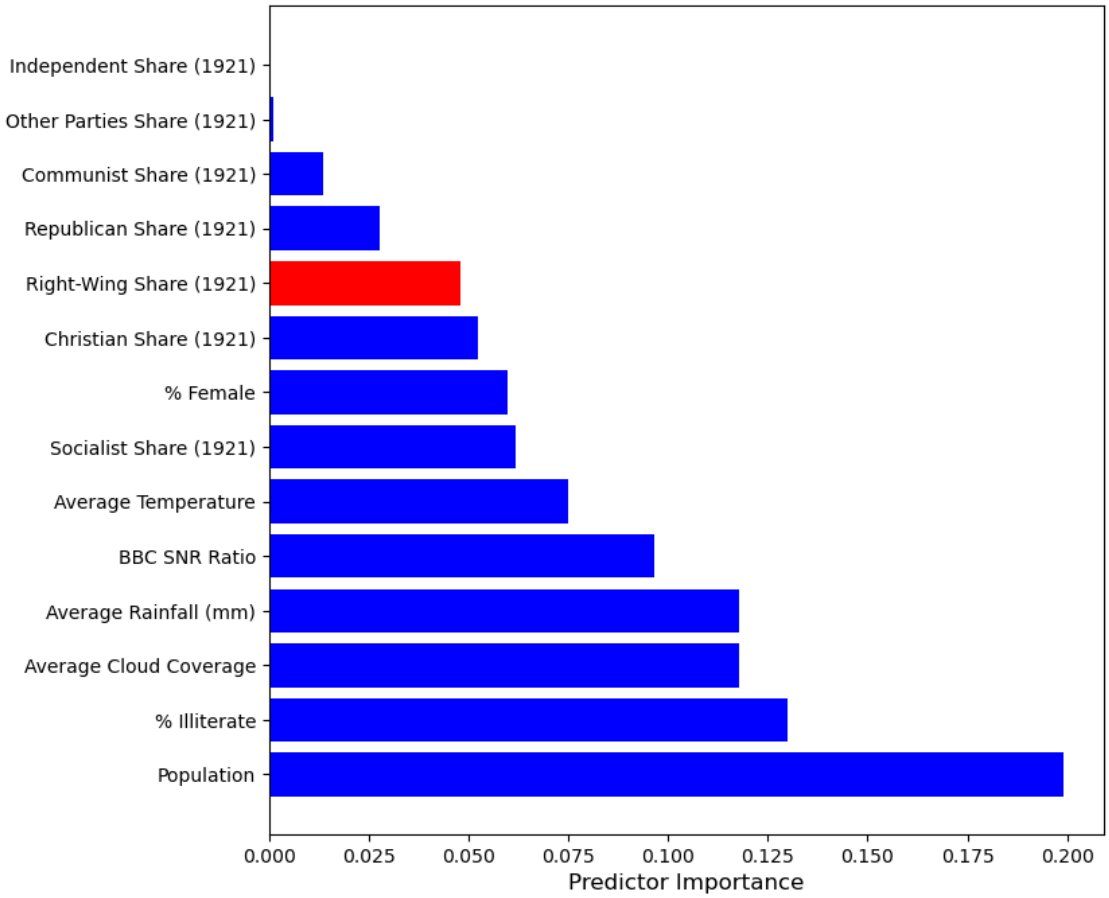


[39]:
```
boost = GradientBoostingRegressor(
    n_estimators=1000,
    learning_rate = 0.1,
    max_depth=5,
    random_state=random_st
)

boost.fit(expl_train, dep_train)
```

[39]:
```
GradientBoostingRegressor(max_depth=5, n_estimators=1000, random_state=55)
```

[40]:
```
dep_pred = boost.predict(expl_test)
print(mean_squared_error(dep_test, dep_pred))

boost_imp = boost.feature_importances_
boost_imp_df = pd.DataFrame({'Predictor Importance': boost_imp}, index=rf_expl.
 ↪columns).sort_values(by='Predictor Importance', ascending=False)
boost_imp_df.index = boost_imp_df.index.map(graph_names_1921)
lbl_col = ['red' if l == 'Right-Wing Share (1921)' else 'blue' for l in␣
 ↪boost_imp_df.index]

boost_imp_pl, lbls = plt.subplots(figsize=(8, 8))
rf_score = lbls.barh(boost_imp_df.index, boost_imp_df['Predictor Importance'],␣
 ↪color=lbl_col)

plt.xlabel('Predictor Importance', fontsize = 12)
plt.gca().legend_ = None
```

```
0.1051664679576247
```



[Model 6] Matching

[41]:
```
ml_data=reg_data.copy()
ml_data['above_median1921'] = (ml_data['aggregated_share1921'] >␣
 ↪ml_data['aggregated_share1921'].median()).astype(int)
```

[42]:
```
controls_matching = ['avg_cloud_coverage', 'avg_rainfall_millimeter',␣
 ↪'avg_temperature',
                     'BBC_SNR_Ratio', 'popul_000s', 'female_share',␣
 ↪'illit_share']
match_data =ml_data.copy()
ate_controls = controls_matching + [party for party in parties_1921 if party !=␣
 ↪'aggregated_share1921']
match_data = match_data.assign(**{c: (match_data[c] - match_data[c].mean())/
 ↪match_data[c].std() for c in ate_controls})
print(ate_controls)
```

```
['avg_cloud_coverage', 'avg_rainfall_millimeter', 'avg_temperature',
'BBC_SNR_Ratio', 'popul_000s', 'female_share', 'illit_share',
```

```
'share_republican1921', 'share_socialist1921', 'share_catholic1921',
'share_communist1921', 'share_independent1921', 'share_altri1921']
```

[43]:
```
def match_f(match_data, ate_controls, match_t, match_y):
    low = match_data.query(f'{match_t} == 0')
    high = match_data.query(f'{match_t} == 1')

    mt_low = KNeighborsRegressor(n_neighbors=1).fit(low[ate_controls],␣
 ↪low[match_y])
    mt_high = KNeighborsRegressor(n_neighbors=1).fit(high[ate_controls],␣
 ↪high[match_y])

    ols_low = LinearRegression().fit(low[ate_controls], low[match_y])
    ols_high = LinearRegression().fit(high[ate_controls], high[match_y])

    high_match_index = mt_low.kneighbors(high[ate_controls], n_neighbors=1)[1].
 ↪ravel()
    low_match_index = mt_high.kneighbors(low[ate_controls], n_neighbors=1)[1].
 ↪ravel()

    matched = pd.concat([
        (high.assign(y_pred=mt_low.predict(high[ate_controls]))
             .assign(bias=ols_low.predict(high[ate_controls]) -
                     ols_low.predict(low.
 ↪iloc[high_match_index][ate_controls]))),
        (low.assign(y_pred=mt_high.predict(low[ate_controls]))
             .assign(bias=ols_high.predict(low[ate_controls]) -
                     ols_high.predict(high.
 ↪iloc[low_match_index][ate_controls]))))
    ])

    atet = np.mean(
        (2 * matched[match_t] - 1) *
        ((matched[match_y] - matched["y_pred"]) - matched["bias"])
    )
    return atet

match_f(match_data, ate_controls, 'above_median1921', 'violence_episode_total')
```

[43]:
$$-0.00500295205656422$$

[49]:
```
match_bootstrap = Parallel(n_jobs=2)(
    delayed(match_f)(
        match_data.sample(n = 16500, replace=True), ate_controls,␣
 ↪'above_median1921', 'violence_episode_total'
    ) for _ in range(100)
)
```

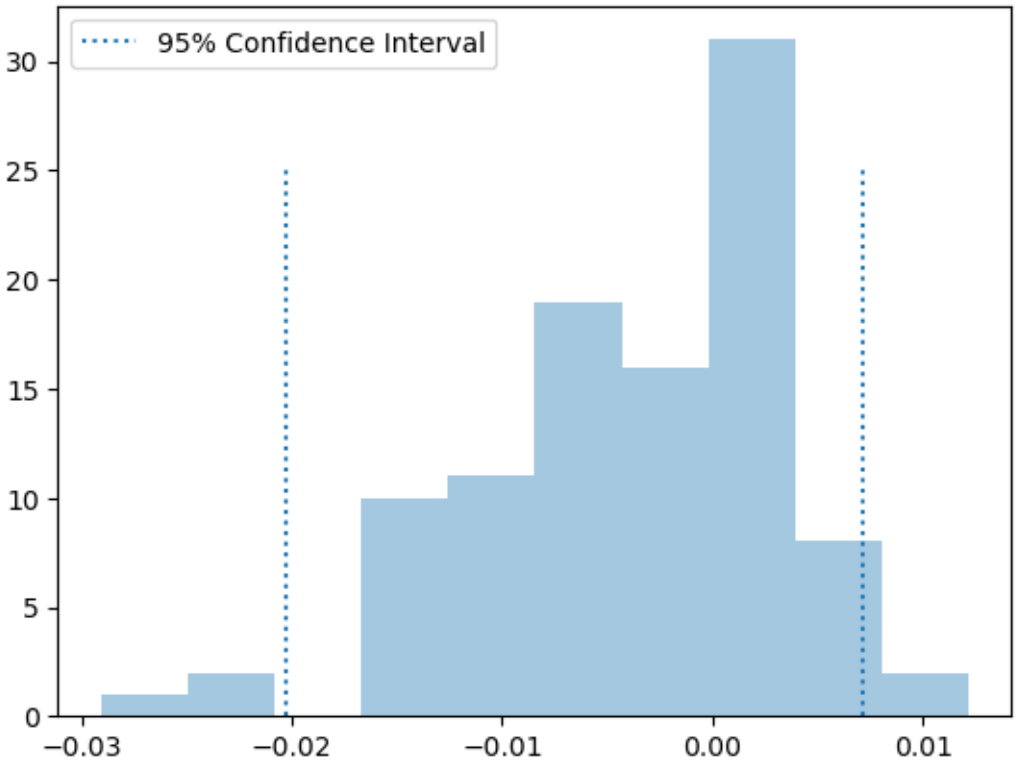
```
match_atet_bootstrap = np.array(match_bootstrap)
```

[50]:
```
print(f"Bootstrap Mean: {np.mean(match_atet_bootstrap)}, Bootstrap SD: {np.
 ↪std(match_atet_bootstrap)},  Bootstrap 2.5: {np.
 ↪percentile(match_atet_bootstrap, 2.5)},  Bootstrap 97.5: {np.
 ↪percentile(match_atet_bootstrap, 97.5)}")
```

```
Bootstrap Mean: -0.0036725968602283575, Bootstrap SD: 0.007292509603986889,
Bootstrap 2.5: -0.020245398133182588,  Bootstrap 97.5: 0.0071764675220646
```

[52]:
```
sns.distplot(match_atet_bootstrap, kde=False)
plt.vlines(np.percentile(match_atet_bootstrap, 2.5), 0, 25, linestyles="dotted")
plt.vlines(np.percentile(match_atet_bootstrap, 97.5), 0, 25,␣
 ↪linestyles="dotted", label="95% Confidence Interval")
plt.legend();
```

```
/tmp/ipykernel_102/3824639655.py:1: UserWarning:

`distplot` is a deprecated function and will be removed in seaborn v0.14.0.

Please adapt your code to use either `displot` (a figure-level function with
similar flexibility) or `histplot` (an axes-level function for histograms).

For a guide to updating your code to use the new functions, please see
https://gist.github.com/mwaskom/de44147ed2974457ad6372750bbe5751

  sns.distplot(match_atet_bootstrap, kde=False)
```



[53]:
```
pre_matching = ml_data.groupby('above_median1921')[ate_controls].mean()
post_matching = match_data.groupby('above_median1921')[ate_controls].mean()

low_before = pre_matching.query('above_median1921 == 0')
high_before = pre_matching.query('above_median1921 == 1')

low_after = post_matching.query('above_median1921 == 0')
high_after = post_matching.query('above_median1921 == 1')

balance = pd.concat([pre_matching.query('above_median1921 == 0').T,
                     pre_matching.query('above_median1921 == 1').T,
                     post_matching.query('above_median1921 == 0').T,
                     post_matching.query('above_median1921 == 1').T],
                     axis=1)

balance_latex = tabulate(balance, headers='keys', tablefmt='latex', floatfmt=".
  ↪3f")
print(balance_latex)
```

```
\begin{tabular}{lrrrr}
\hline
                         &      0 &      1 &      0 &      1 \\
```

```
\hline
 avg\_cloud\_coverage      & 57.249 & 57.231 &  0.001 & -0.001 \\
 avg\_rainfall\_millimeter & 72.993 & 70.730 &  0.018 & -0.018 \\
 avg\_temperature         & 11.279 & 12.063 & -0.049 &  0.049 \\
 BBC\_SNR\_Ratio           & 59.730 & 59.045 &  0.063 & -0.063 \\
 popul\_000s              &  3.931 &  7.150 & -0.050 &  0.050 \\
 female\_share            &  0.503 &  0.503 &  0.008 & -0.008 \\
 illit\_share             &  0.051 &  0.063 & -0.116 &  0.116 \\
 share\_republican1921    &  0.007 &  0.010 & -0.040 &  0.040 \\
 share\_socialist1921     &  0.149 &  0.307 & -0.347 &  0.347 \\
 share\_catholic1921      &  0.344 &  0.254 &  0.229 & -0.229 \\
 share\_communist1921     &  0.018 &  0.044 & -0.183 &  0.183 \\
 share\_independent1921   &  0.000 &  0.000 &  0.029 & -0.029 \\
 share\_altri1921         &  0.000 &  0.000 & -0.049 &  0.049 \\
\hline
\end{tabular}
```

[Model 7] IPW

[54]:
```
ipw_data = ml_data.copy()
ipw_x = ['avg_cloud_coverage', 'avg_rainfall_millimeter', 'avg_temperature',
                     'BBC_SNR_Ratio', 'popul_000s', 'female_share',␣
 ↪'illit_share'] + [party for party in parties_1921 if party !=␣
 ↪'aggregated_share1921']
ipw_t = 'above_median1921'
ipw_y = 'violence_episode_total'
```

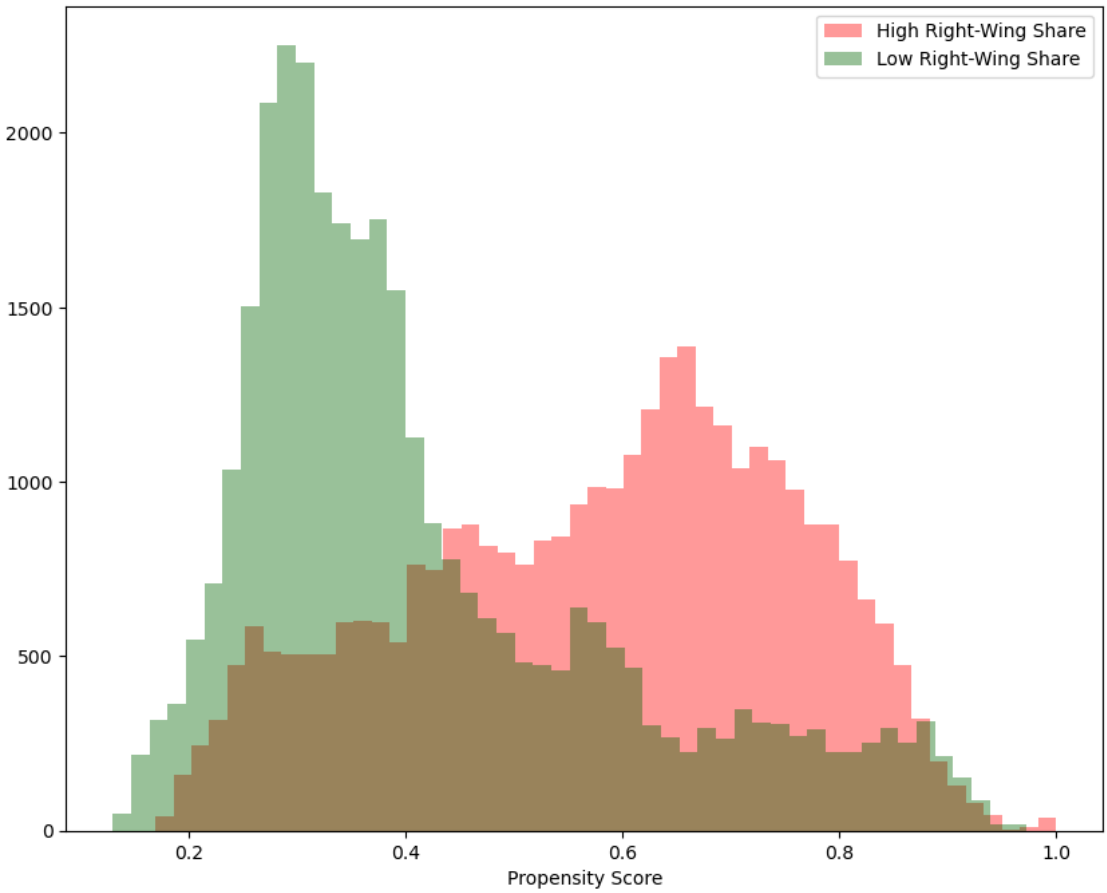
[55]:
```
def ipw_bootstrap(ipw_data, ipw_x, ipw_t, ipw_y):

    ipw_lr_fit = LogisticRegression(C=1e6, max_iter=1000,␣
 ↪random_state=random_st, penalty='l2').fit(ipw_data[ipw_x], ipw_data[ipw_t])

    ipw_data = ipw_data.assign(ps=ipw_lr_fit.predict_proba(ipw_data[ipw_x])[:,␣
 ↪1])

    high_w = 1 / ipw_data.query('above_median1921 == 1')["ps"]
    low_w = 1 / (1 - ipw_data.query('above_median1921 == 0')["ps"])

    w = ((ipw_data['above_median1921'] - ipw_data["ps"]) /
         (ipw_data["ps"] * (1 - ipw_data["ps"])))

    viol1 = sum(ipw_data.query('above_median1921 ==␣
 ↪1')["violence_episode_total"] * high_w) / len(ipw_data)
    viol0 = sum(ipw_data.query('above_median1921 ==␣
 ↪0')["violence_episode_total"] * low_w) / len(ipw_data)

    ate = np.mean(w * ipw_data["violence_episode_total"])
```

```
    return viol1, viol0, ate
```

[56]:
```
ipw_lr_fit = LogisticRegression(C=1e6, max_iter=1000, random_state=random_st,␣
 ↪penalty='l2').fit(ipw_data[ipw_x], ipw_data[ipw_t])

ipw_data = ipw_data.assign(ps=ipw_lr_fit.predict_proba(ipw_data[ipw_x])[:, 1])

plt.figure(figsize=(10, 8))

sns.distplot(ipw_data.query('above_median1921==1')['ps'],
                 kde=False, label="High Right-Wing Share", color="red")

sns.distplot(ipw_data.query('above_median1921==0')['ps'],
                 kde=False, label="Low Right-Wing Share", color="darkgreen")

plt.xlabel('Propensity Score')
plt.legend()
```

```
/tmp/ipykernel_102/1502782447.py:7: UserWarning:

`distplot` is a deprecated function and will be removed in seaborn v0.14.0.

Please adapt your code to use either `displot` (a figure-level function with
similar flexibility) or `histplot` (an axes-level function for histograms).

For a guide to updating your code to use the new functions, please see
https://gist.github.com/mwaskom/de44147ed2974457ad6372750bbe5751

  sns.distplot(ipw_data.query('above_median1921==1')['ps'],
/tmp/ipykernel_102/1502782447.py:10: UserWarning:

`distplot` is a deprecated function and will be removed in seaborn v0.14.0.

Please adapt your code to use either `displot` (a figure-level function with
similar flexibility) or `histplot` (an axes-level function for histograms).

For a guide to updating your code to use the new functions, please see
https://gist.github.com/mwaskom/de44147ed2974457ad6372750bbe5751

  sns.distplot(ipw_data.query('above_median1921==0')['ps'],
```

[56]:
```
<matplotlib.legend.Legend at 0x7fac1ecb0890>
```



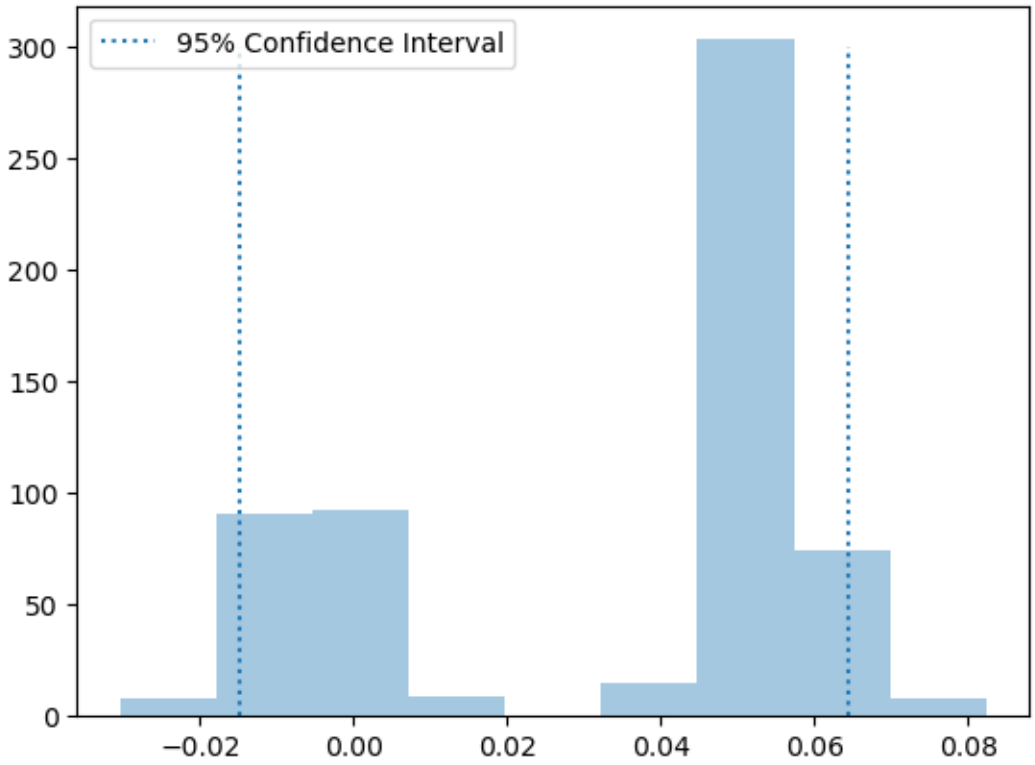
[57]:
```
ipw_atets = Parallel(n_jobs=2)(delayed(ipw_bootstrap)(
            ipw_data.sample(n=16500, replace=True), ipw_x, ipw_t, ipw_y)
                                    for _ in range(200))

ipw_atets = np.array(ipw_atets)
```

[58]:
```
print(f"IPW Mean: {np.mean(ipw_atets)}, IPW SD: {np.std(ipw_atets)},  IPW 2.5:␣
  ↪{np.percentile(ipw_atets, 2.5)},  IPW 97.5: {np.percentile(ipw_atets, 97.
  ↪5)}")
```

```
IPW Mean: 0.033979119094721885, IPW SD: 0.028312697094344034,  IPW 2.5:
-0.014779988047586163,  IPW 97.5: 0.06447284781908638
```

[59]:
```
sns.distplot(ipw_atets, kde=False)
plt.vlines(np.percentile(ipw_atets, 2.5), 0, 300, linestyles="dotted")
plt.vlines(np.percentile(ipw_atets, 97.5), 0, 300, linestyles="dotted",␣
  ↪label="95% Confidence Interval")
plt.legend();
```

```
/tmp/ipykernel_102/3309824213.py:1: UserWarning:

`distplot` is a deprecated function and will be removed in seaborn v0.14.0.

Please adapt your code to use either `displot` (a figure-level function with
similar flexibility) or `histplot` (an axes-level function for histograms).

For a guide to updating your code to use the new functions, please see
https://gist.github.com/mwaskom/de44147ed2974457ad6372750bbe5751

  sns.distplot(ipw_atets, kde=False)
```



[Model 9] Meta Learners

[60]:
```
lgbm_max = 5
child = 150
learn_rate = 0.1
```

[61]:
```
controls_matching = ['avg_cloud_coverage', 'avg_rainfall_millimeter',␣
↪'avg_temperature',
                     'BBC_SNR_Ratio', 'popul_000s', 'female_share',␣
↪'illit_share']
```

```
meta_data =ml_data.copy()
meta_x = controls_matching + [party for party in parties_1921 if party !=␣
 ↪'aggregated_share1921']

meta_train, meta_test = train_test_split(meta_data, test_size=0.25,␣
 ↪random_state=random_st)
meta_y = 'violence_episode_total'
meta_t= 'above_median1921'
meta_train = meta_train[meta_x + [meta_y, meta_t]]
meta_test = meta_test[meta_x + [meta_y, meta_t]]

logit = LogisticRegression(solver="lbfgs", penalty='l2', max_iter=1000,␣
 ↪random_state = random_st)

ml_z = LGBMRegressor(max_depth=lgbm_max, min_child_samples=child, learning_rate␣
 ↪=learn_rate, random_state=random_st)
ml_o = LGBMRegressor(max_depth=lgbm_max, min_child_samples=child, learning_rate␣
 ↪=learn_rate, random_state=random_st)
ml_z.fit(meta_train.query('above_median1921 == 0')[meta_x], meta_train.
 ↪query('above_median1921 == 0')[meta_y])
ml_o.fit(meta_test.query('above_median1921 == 1')[meta_x], meta_test.
 ↪query('above_median1921 == 1')[meta_y])
logit.fit(meta_train[meta_x], meta_train[meta_t]);

d_tr = np.where(meta_train[meta_t]==0,
                  ml_o.predict(meta_train[meta_x]) - meta_train[meta_y],
                  meta_train[meta_y] - ml_z.predict(meta_train[meta_x]))

s_ml_z = LGBMRegressor(max_depth=lgbm_max, min_child_samples=child,␣
 ↪learning_rate =learn_rate, random_state=random_st)
s_ml_o = LGBMRegressor(max_depth=lgbm_max, min_child_samples=child,␣
 ↪learning_rate =learn_rate, random_state=random_st)

s_ml_z.fit(meta_train.query('above_median1921 == 0')[meta_x],␣
 ↪d_tr[meta_train[meta_t]==0])
s_ml_o.fit(meta_train.query('above_median1921 == 1')[meta_x],␣
 ↪d_tr[meta_train[meta_t]==1]);

x_meta_train_cate = (logit.predict_proba(meta_train[meta_x])[:, 1]*s_ml_z.
 ↪predict(meta_train[meta_x]) +
                logit.predict_proba(meta_train[meta_x])[:, 0]*s_ml_o.
 ↪predict(meta_train[meta_x]))

x_meta_test_cate = meta_test.assign(
    cate=(
```

```
        logit.predict_proba(meta_test[meta_x])[:, 1] * s_ml_z.
↪predict(meta_test[meta_x]) +
        logit.predict_proba(meta_test[meta_x])[:, 0] * s_ml_o.
↪predict(meta_test[meta_x])
    )
)
```

```
[LightGBM] [Info] Auto-choosing row-wise multi-threading, the overhead of
testing was 0.001378 seconds.
You can set `force_row_wise=true` to remove the overhead.
And if memory is not enough, you can set `force_col_wise=true`.
[LightGBM] [Info] Total Bins 2404
[LightGBM] [Info] Number of data points in the train set: 24838, number of used
features: 13
[LightGBM] [Info] Start training from score 0.044045
[LightGBM] [Warning] No further splits with positive gain, best gain: -inf
[LightGBM] [Warning] No further splits with positive gain, best gain: -inf
[LightGBM] [Warning] No further splits with positive gain, best gain: -inf
[LightGBM] [Warning] No further splits with positive gain, best gain: -inf
[LightGBM] [Warning] No further splits with positive gain, best gain: -inf
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[LightGBM] [Warning] No further splits with positive gain, best gain: -inf
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[LightGBM] [Warning] No further splits with positive gain, best gain: -inf
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[LightGBM] [Info] Auto-choosing col-wise multi-threading, the overhead of
testing was 0.000228 seconds.
You can set `force_col_wise=true` to remove the overhead.
[LightGBM] [Info] Total Bins 2534
[LightGBM] [Info] Number of data points in the train set: 8301, number of used
features: 12
[LightGBM] [Info] Start training from score 0.057945
[LightGBM] [Warning] No further splits with positive gain, best gain: -inf
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[LightGBM] [Warning] No further splits with positive gain, best gain: -inf
[LightGBM] [Info] Auto-choosing col-wise multi-threading, the overhead of
testing was 0.001735 seconds.
You can set `force_col_wise=true` to remove the overhead.
[LightGBM] [Info] Total Bins 2404
[LightGBM] [Info] Number of data points in the train set: 24838, number of used
features: 13
[LightGBM] [Info] Start training from score 0.003022
[LightGBM] [Warning] No further splits with positive gain, best gain: -inf
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[LightGBM] [Warning] No further splits with positive gain, best gain: -inf
[LightGBM] [Warning] No further splits with positive gain, best gain: -inf
[LightGBM] [Info] Auto-choosing row-wise multi-threading, the overhead of
testing was 0.000579 seconds.
You can set `force_row_wise=true` to remove the overhead.
And if memory is not enough, you can set `force_col_wise=true`.
[LightGBM] [Info] Total Bins 2535
[LightGBM] [Info] Number of data points in the train set: 24767, number of used
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features: 12
[LightGBM] [Info] Start training from score 0.006559
[LightGBM] [Warning] No further splits with positive gain, best gain: -inf
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[62]:
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x_meta_test_curve = cumulative_gain(x_meta_test_cate, "cate", y=meta_y,␣
 ↪t=meta_t)
x_meta_train_curve = cumulative_gain(meta_train.assign(cate=x_meta_train_cate),␣
 ↪"cate", y=meta_y, t=meta_t)
plt.plot(x_meta_test_curve, color="C0", label="Test")
plt.plot(x_meta_train_curve, color="C1", label="Train")
plt.plot([0, 100], [0, elast(meta_train, meta_y, meta_t)], linestyle="--",␣
 ↪color="black", label="Baseline")
plt.legend();
```
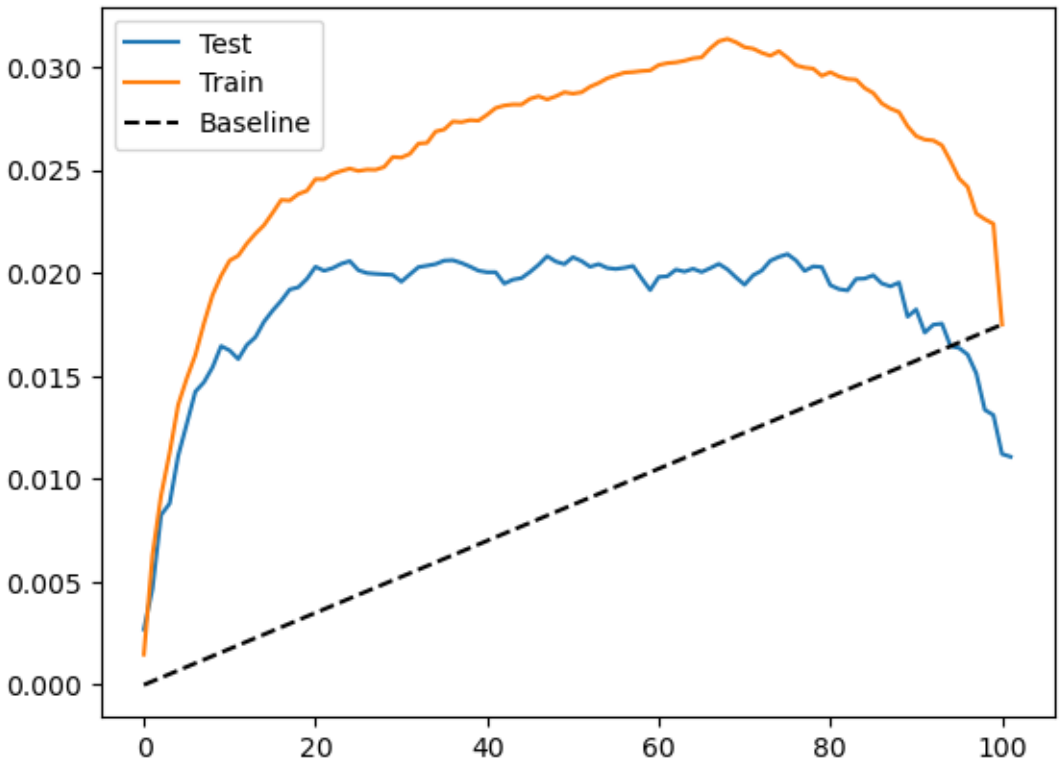
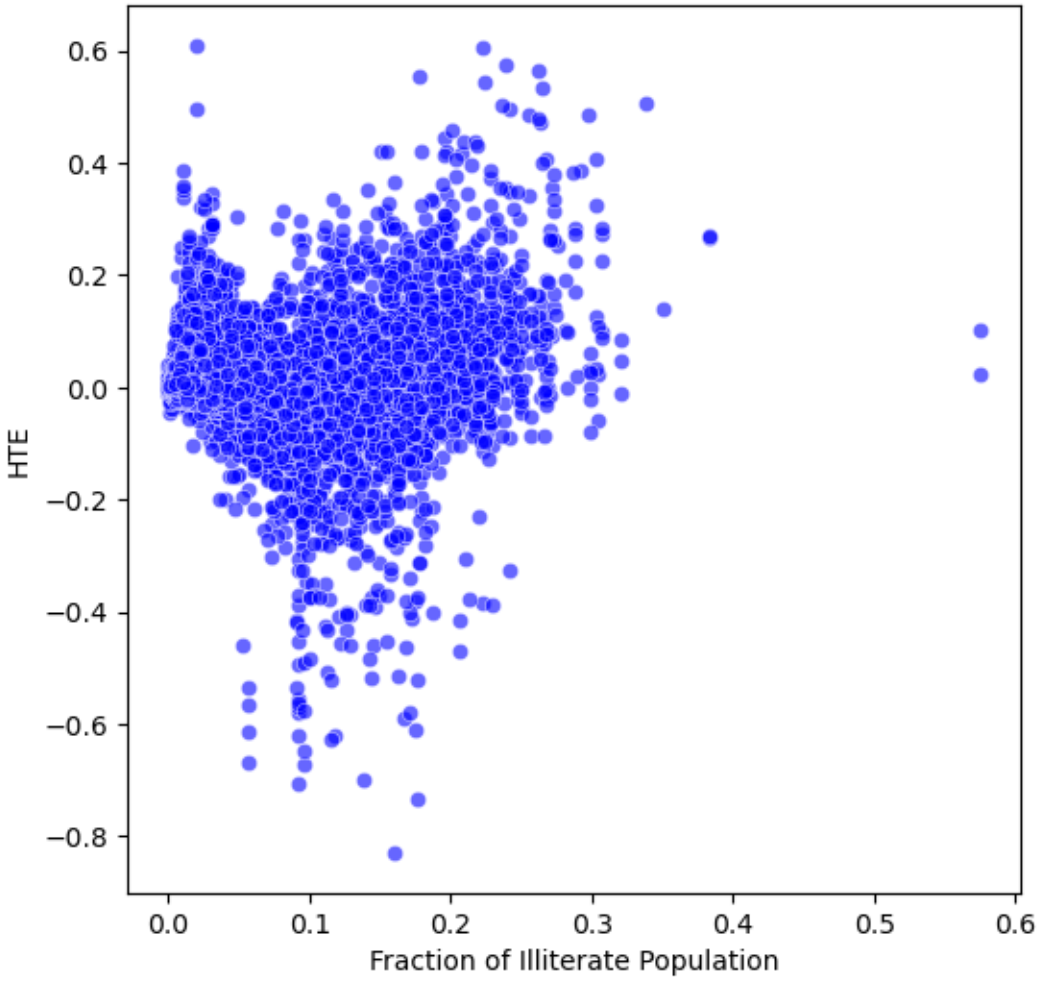



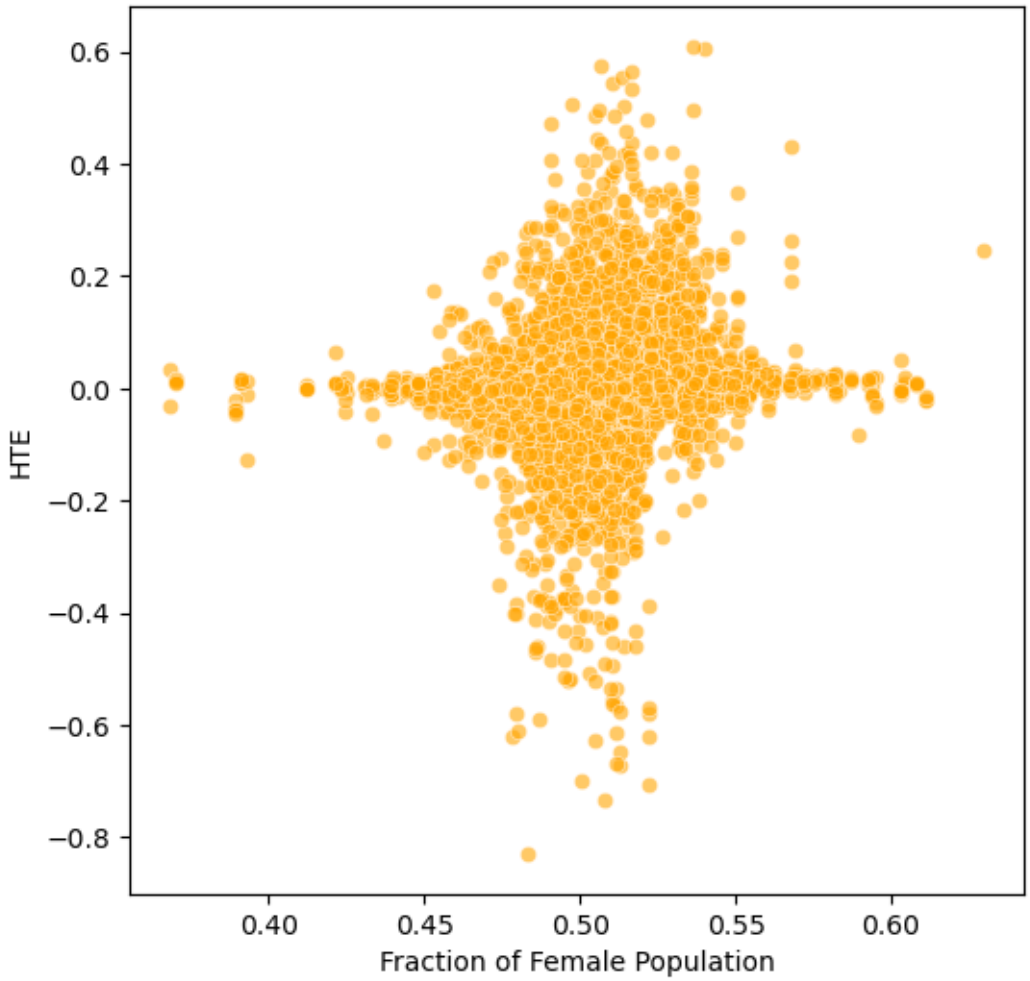
[63]:
```
plt.figure(figsize=(6, 6))
sns.scatterplot(data=x_meta_test_cate, x='illit_share', y='cate', color =␣
 ↪'blue', alpha=0.6)
plt.xlabel('Fraction of Illiterate Population')
plt.ylabel('HTE')
```

[63]: Text(0, 0.5, 'HTE')



[64]:
```
plt.figure(figsize=(6, 6))
sns.scatterplot(data=x_meta_test_cate, x='female_share', y='cate', color =␣
↪'orange', alpha=0.6)
plt.xlabel('Fraction of Female Population')
plt.ylabel('HTE')
```

[64]: Text(0, 0.5, 'HTE')



[65]:
```
meta_train, meta_test = train_test_split(meta_data, test_size=0.25,␣
 ↪random_state=55)
meta_train = meta_train[meta_x + [meta_y, meta_t]]
meta_test = meta_test[meta_x + [meta_y, meta_t]]

t_0 = LGBMRegressor(max_depth=lgbm_max, min_child_samples=child, learning_rate␣
 ↪=learn_rate, random_state = random_st)
t_1 = LGBMRegressor(max_depth=lgbm_max, min_child_samples=child, learning_rate␣
 ↪=learn_rate, random_state = random_st)

t_0.fit(meta_train.query('above_median1921 == 0')[meta_x], meta_train.
 ↪query('above_median1921 == 0')[meta_y])
t_1.fit(meta_train.query('above_median1921 == 1')[meta_x], meta_train.
 ↪query('above_median1921 == 1')[meta_y])
```

```python
t_meta_train_cate = t_1.predict(meta_train[meta_x]) - t_0.
 ↪predict(meta_train[meta_x])
t_meta_test_cate = meta_test.assign(cate=t_1.predict(meta_test[meta_x]) - t_0.
 ↪predict(meta_test[meta_x]))
```

```
[LightGBM] [Info] Auto-choosing row-wise multi-threading, the overhead of
testing was 0.000752 seconds.
You can set `force_row_wise=true` to remove the overhead.
And if memory is not enough, you can set `force_col_wise=true`.
[LightGBM] [Info] Total Bins 2404
[LightGBM] [Info] Number of data points in the train set: 24838, number of used
features: 13
[LightGBM] [Info] Start training from score 0.044045
[LightGBM] [Warning] No further splits with positive gain, best gain: -inf
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[LightGBM] [Warning] No further splits with positive gain, best gain: -inf
[LightGBM] [Info] Auto-choosing col-wise multi-threading, the overhead of
testing was 0.000858 seconds.
You can set `force_col_wise=true` to remove the overhead.
[LightGBM] [Info] Total Bins 2535
[LightGBM] [Info] Number of data points in the train set: 24767, number of used
features: 12
[LightGBM] [Info] Start training from score 0.061533
[LightGBM] [Warning] No further splits with positive gain, best gain: -inf
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```
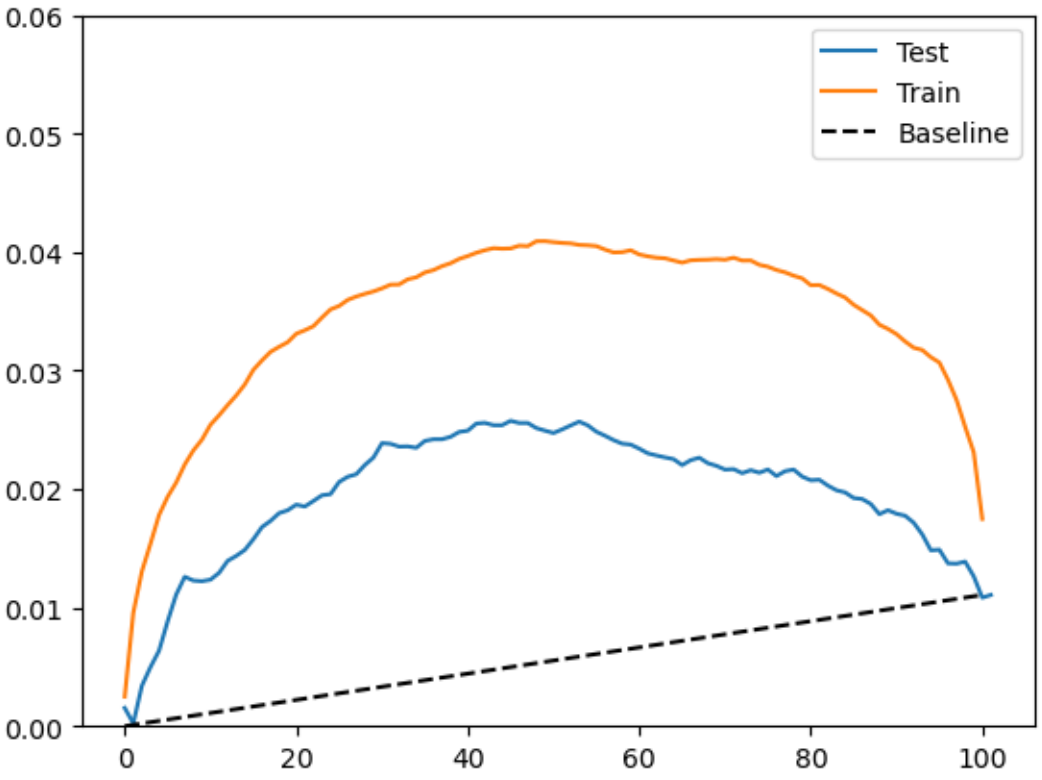
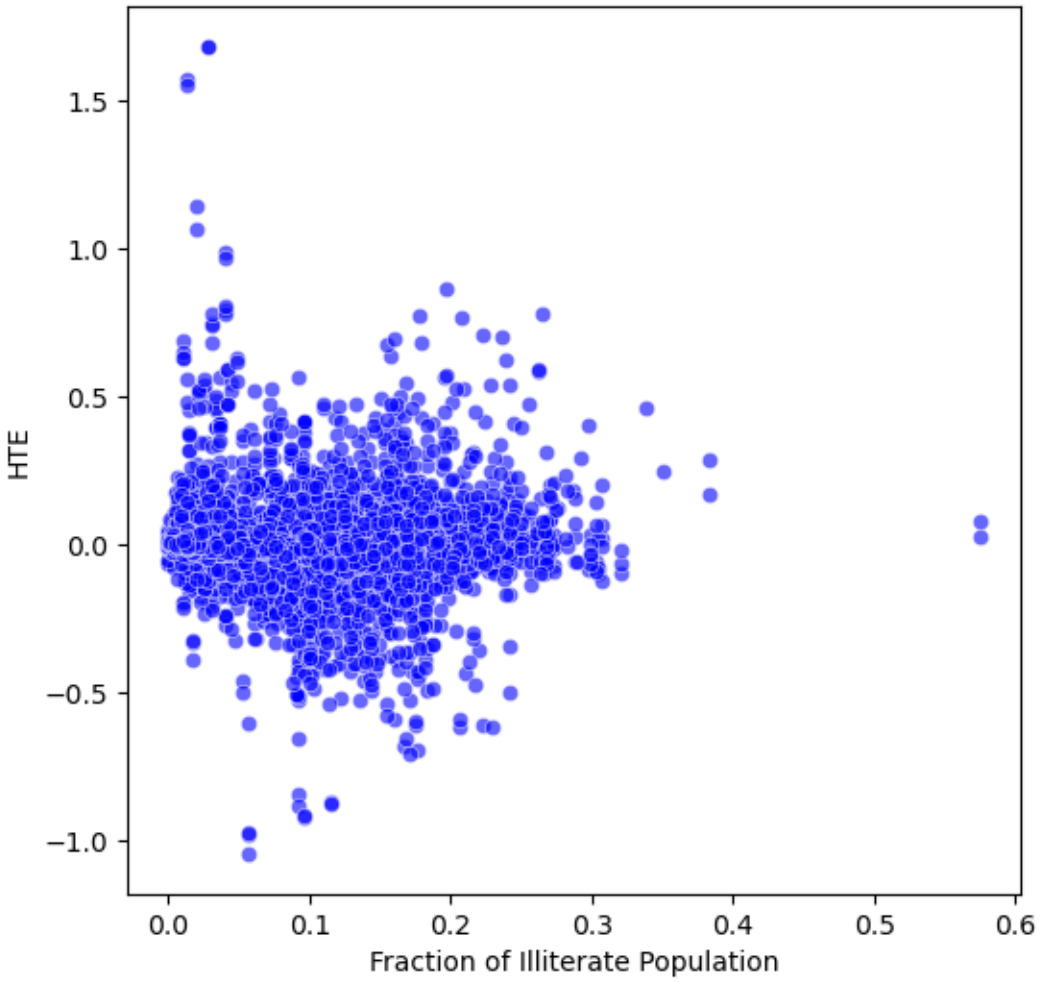

[66]:

```python
t_meta_test_curve = cumulative_gain(t_meta_test_cate, "cate", y=meta_y,␣
 ↪t=meta_t)
t_meta_train_curve = cumulative_gain(meta_train.assign(cate=t_meta_train_cate),␣
 ↪"cate", y=meta_y, t=meta_t)
plt.plot(t_meta_test_curve, color="C0", label="Test")
plt.plot(t_meta_train_curve, color="C1", label="Train")
plt.plot([0, 100], [0, elast(meta_test, meta_y, meta_t)], linestyle="--",␣
 ↪color="black", label="Baseline")
plt.legend()
plt.ylim(0, 0.06);
```



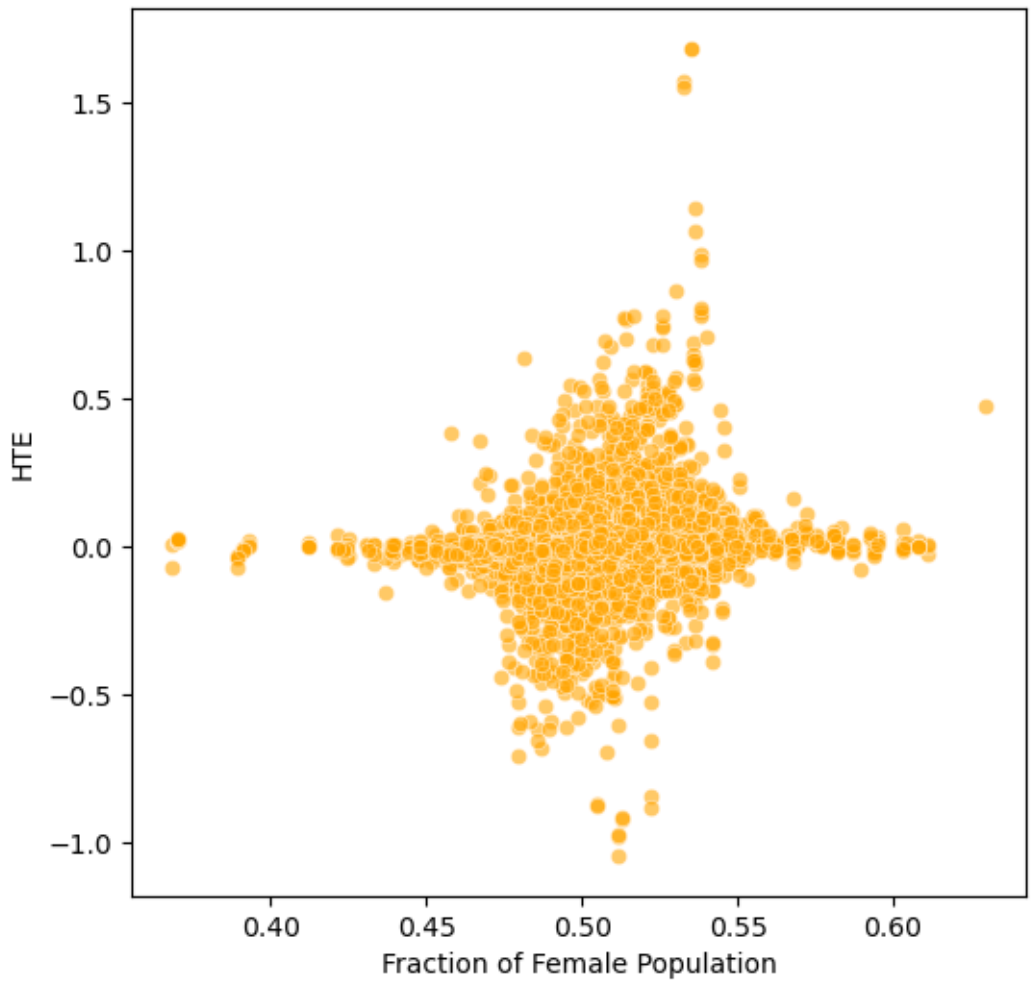
[67]:
```
plt.figure(figsize=(6, 6))
sns.scatterplot(data=t_meta_test_cate, x='illit_share', y='cate', color =␣
↪'blue', alpha=0.6)
plt.xlabel('Fraction of Illiterate Population')
plt.ylabel('HTE')
```

[67]:
```
Text(0, 0.5, 'HTE')
```



[68]:
```
plt.figure(figsize=(6, 6))
sns.scatterplot(data=t_meta_test_cate, x='female_share', y='cate', color =␣
↪'orange', alpha=0.6)
plt.xlabel('Fraction of Female Population')
plt.ylabel('HTE')
```

[68]:
```
Text(0, 0.5, 'HTE')
```



[69]:
```
controls_matching = ['avg_cloud_coverage', 'avg_rainfall_millimeter',␣
 ↪'avg_temperature',
                     'BBC_SNR_Ratio', 'popul_000s', 'female_share',␣
 ↪'illit_share']

meta_x = controls_matching + [party for party in parties_1921 if party !=␣
 ↪'aggregated_share1921']

xy = ['violence_episode_total', 'above_median1921']
ns = xy +meta_x

dirs = []

for v in meta_x:
    for x in xy:
        dirs.append((v, x))
```

```
dirs = dirs + [('above_median1921', 'violence_episode_total')]

print(dirs)

meta_graph = 'graph [directed 1\n'
for n in ns:
    meta_graph += f'\tnode [id "{n}" label "{n}"]\n'
for d in dirs:
    meta_graph += f'\tedge [source "{d[0]}" target "{d[1]}"]\n'
meta_graph += ']'

meta_cate = CausalModel(
    data=meta_test,
    treatment='above_median1921',
    outcome='violence_episode_total',
    effect_modifiers=meta_x,
    graph=meta_graph
)
```

```
[('avg_cloud_coverage', 'violence_episode_total'), ('avg_cloud_coverage',
'above_median1921'), ('avg_rainfall_millimeter', 'violence_episode_total'),
('avg_rainfall_millimeter', 'above_median1921'), ('avg_temperature',
'violence_episode_total'), ('avg_temperature', 'above_median1921'),
('BBC_SNR_Ratio', 'violence_episode_total'), ('BBC_SNR_Ratio',
'above_median1921'), ('popul_000s', 'violence_episode_total'), ('popul_000s',
'above_median1921'), ('female_share', 'violence_episode_total'),
('female_share', 'above_median1921'), ('illit_share', 'violence_episode_total'),
('illit_share', 'above_median1921'), ('share_republican1921',
'violence_episode_total'), ('share_republican1921', 'above_median1921'),
('share_socialist1921', 'violence_episode_total'), ('share_socialist1921',
'above_median1921'), ('share_catholic1921', 'violence_episode_total'),
('share_catholic1921', 'above_median1921'), ('share_communist1921',
'violence_episode_total'), ('share_communist1921', 'above_median1921'),
('share_independent1921', 'violence_episode_total'), ('share_independent1921',
'above_median1921'), ('share_altri1921', 'violence_episode_total'),
('share_altri1921', 'above_median1921'), ('above_median1921',
'violence_episode_total')]
```

[70]:
```
x_dep_cate = meta_cate.identify_effect()
x_expl_cate = meta_cate.estimate_effect(
    identified_estimand=x_dep_cate,
    method_name='backdoor.econml.metalearners.XLearner',
    target_units='ate',
    method_params={
        'init_params': {
            'models': [
```

```
                LGBMRegressor(max_depth=lgbm_max, min_child_samples=child,␣
↪learning_rate =learn_rate, random_state=random_st),
                LGBMRegressor(max_depth=lgbm_max, min_child_samples=child,␣
↪learning_rate =learn_rate, random_state=random_st)
            ],
            'cate_models': [
                LGBMRegressor(max_depth=lgbm_max, min_child_samples=child,␣
↪learning_rate =learn_rate, random_state=random_st),
                LGBMRegressor(max_depth=lgbm_max, min_child_samples=child,␣
↪learning_rate =learn_rate, random_state=random_st)
            ]
        },
        'fit_params': {},
    })
```

```
A column-vector y was passed when a 1d array was expected. Please change the
shape of y to (n_samples, ), for example using ravel().
```

```
[LightGBM] [Info] Auto-choosing col-wise multi-threading, the overhead of
testing was 0.000608 seconds.
You can set `force_col_wise=true` to remove the overhead.
[LightGBM] [Info] Total Bins 2345
[LightGBM] [Info] Number of data points in the train set: 8235, number of used
features: 12
[LightGBM] [Info] Start training from score 0.046873
[LightGBM] [Warning] No further splits with positive gain, best gain: -inf
[LightGBM] [Warning] No further splits with positive gain, best gain: -inf
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[LightGBM] [Info] Auto-choosing col-wise multi-threading, the overhead of
testing was 0.000258 seconds.
You can set `force_col_wise=true` to remove the overhead.
[LightGBM] [Info] Total Bins 2534
[LightGBM] [Info] Number of data points in the train set: 8301, number of used
features: 12
[LightGBM] [Info] Start training from score 0.057945
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[LightGBM] [Info] Auto-choosing col-wise multi-threading, the overhead of
testing was 0.000616 seconds.
You can set `force_col_wise=true` to remove the overhead.
[LightGBM] [Info] Total Bins 2345
[LightGBM] [Info] Number of data points in the train set: 8235, number of used
features: 12
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[LightGBM] [Info] Auto-choosing col-wise multi-threading, the overhead of
testing was 0.000235 seconds.
You can set `force_col_wise=true` to remove the overhead.
[LightGBM] [Info] Total Bins 2534
[LightGBM] [Info] Number of data points in the train set: 8301, number of used
features: 12
[LightGBM] [Info] Start training from score -0.002495
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```
lbfgs failed to converge (status=1):
STOP: TOTAL NO. of ITERATIONS REACHED LIMIT.

Increase the number of iterations (max_iter) or scale the data as shown in:
    https://scikit-learn.org/stable/modules/preprocessing.html
Please also refer to the documentation for alternative solver options:
    https://scikit-learn.org/stable/modules/linear_model.html#logistic-
regression
```

[71]:

```
x_expl_cate.cate_estimates.mean()
```

[71]:

$-0.0002406131854612\overline{9}1$

[72]:

```
t_dep_cate = meta_cate.identify_effect()
t_expl_cate = meta_cate.estimate_effect(
    identified_estimand=t_dep_cate,
    method_name='backdoor.econml.metalearners.TLearner',
    target_units='ate',
    method_params={
        'init_params': {
            'models': [
                LGBMRegressor(max_depth=lgbm_max, min_child_samples=child,␣
 ↪learning_rate =learn_rate, random_state=random_st),
                LGBMRegressor(max_depth=lgbm_max, min_child_samples=child,␣
 ↪learning_rate =learn_rate, random_state=random_st)
            ]
        },
        'fit_params': {}
    })
```

```
[LightGBM] [Info] Auto-choosing col-wise multi-threading, the overhead of
testing was 0.000609 seconds.
You can set `force_col_wise=true` to remove the overhead.
[LightGBM] [Info] Total Bins 2345
```

```
[LightGBM] [Info] Number of data points in the train set: 8235, number of used
features: 12
[LightGBM] [Info] Start training from score 0.046873
[LightGBM] [Warning] No further splits with positive gain, best gain: -inf
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[LightGBM] [Warning] No further splits with positive gain, best gain: -inf
[LightGBM] [Info] Auto-choosing col-wise multi-threading, the overhead of
testing was 0.000235 seconds.
You can set `force_col_wise=true` to remove the overhead.
[LightGBM] [Info] Total Bins 2534
[LightGBM] [Info] Number of data points in the train set: 8301, number of used
features: 12
[LightGBM] [Info] Start training from score 0.057945
[LightGBM] [Warning] No further splits with positive gain, best gain: -inf
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```

```
A column-vector y was passed when a 1d array was expected. Please change the
shape of y to (n_samples, ), for example using ravel().
```

[73]:

```
t_expl_cate.cate_estimates.mean()
```

[73]: −0.000668229481536027

Doubly Robust

[74]:

```
dr_x = ['avg_cloud_coverage', 'avg_rainfall_millimeter', 'avg_temperature',
                     'BBC_SNR_Ratio', 'popul_000s', 'female_share',␣
↪'illit_share'] + [party for party in parties_1921 if party !=␣
↪'aggregated_share1921']
dr_t = 'above_median1921'
dr_y = 'violence_episode_total'
dr_data = ml_data.copy()
```

[75]:

```
def dr_bootstrap(dr_data, dr_x, dr_t, dr_y):
    ps = LogisticRegression(penalty='l2', max_iter=1000, random_state =␣
↪random_st).fit(dr_data[dr_x], dr_data[dr_t]).predict_proba(dr_data[dr_x])[:,␣
↪1]
    low_dr = LinearRegression().fit(dr_data.query(f'{dr_t}==0')[dr_x], dr_data.
↪query(f'{dr_t}==0')[dr_y]).predict(dr_data[dr_x])
    high_dr = LinearRegression().fit(dr_data.query(f'{dr_t}==1')[dr_x], dr_data.
↪query(f'{dr_t}==1')[dr_y]).predict(dr_data[dr_x])
    dr_ate = (
        np.mean(dr_data[dr_t]*(dr_data[dr_y] - high_dr)/ps + high_dr) -
        np.mean((1-dr_data[dr_t])*(dr_data[dr_y] - low_dr)/(1-ps) + low_dr)
    )
```

```
    return dr_ate

dr_bootstrap(dr_data, dr_x, dr_t, dr_y)
```

[75]:
$$-0.004114832783564$$

[76]:
```
dr_atets = Parallel(n_jobs=2)(delayed(dr_bootstrap)
                              (dr_data.sample(n=16500, replace=True), dr_x,␣
 ↪dr_t, dr_y)
                                    for _ in range(200))

dr_atets = np.array(dr_atets)
```

[77]:
```
print(f"DR Mean: {np.mean(dr_atets)}, DR SD: {np.std(dr_atets)},  DR 2.5: {np.
 ↪percentile(dr_atets, 2.5)},  DR 97.5: {np.percentile(dr_atets, 97.5)}")
```

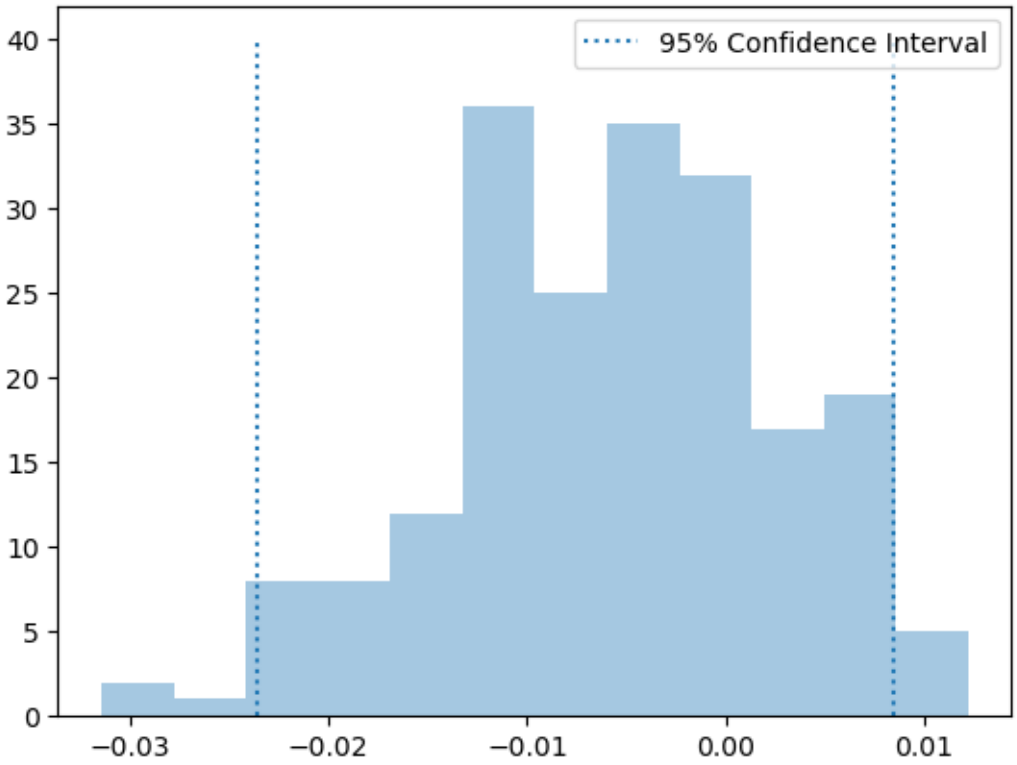
```
DR Mean: -0.005599877330580244, DR SD: 0.008427320599267315,  DR 2.5:
-0.0236378962912684,  DR 97.5: 0.00848330957193274
```

[78]:
```
sns.distplot(dr_atets, kde=False)
plt.vlines(np.percentile(dr_atets, 2.5), 0, 40, linestyles="dotted")
plt.vlines(np.percentile(dr_atets, 97.5), 0, 40, linestyles="dotted",␣
 ↪label="95% Confidence Interval")
plt.legend();
```

```
`distplot` is a deprecated function and will be removed in seaborn v0.14.0.

Please adapt your code to use either `displot` (a figure-level function with
similar flexibility) or `histplot` (an axes-level function for histograms).

For a guide to updating your code to use the new functions, please see
https://gist.github.com/mwaskom/de44147ed2974457ad6372750bbe5751
```



[Model 11] Double Machine Learning

[79]:
```
controls_matching = ['avg_cloud_coverage', 'avg_rainfall_millimeter',␣
 ↪'avg_temperature',
                     'BBC_SNR_Ratio', 'popul_000s', 'female_share',␣
 ↪'illit_share']

dml_data = ml_data.copy()
list_x = controls_matching + [party for party in parties_1921 if party !=␣
 ↪'aggregated_share1921'] + ['above_median1921']

dml_x = dml_data[list_x]
dml_y = dml_data['violence_episode_total']
dml_x_train, dml_x_test, dml_y_train, dml_y_test = train_test_split(dml_x,␣
 ↪dml_y, test_size=0.25, random_state=random_st)
dml_train = pd.concat([dml_x_train, dml_y_train], axis=1)
dml_test = pd.concat([dml_x_test, dml_y_test], axis=1)
dml_bias = LGBMRegressor(max_depth=3, random_state = random_st)
```

[80]:
```
dml_y = "violence_episode_total"
dml_t = "above_median1921"
```

```
dml_x =  controls_matching + [party for party in parties_1921 if party !=␣
 ↪'aggregated_share1921']

dml_noise = LGBMRegressor(max_depth=3, random_state = random_st)
```

```
[81]: dml_train_nonlin = dml_train.copy()
      dml_test_nonlin = dml_test.copy()

      dml_train_pred_nonlin = dml_train_nonlin.assign(exp_res =
                                                  dml_train_nonlin[dml_t] -
                                                  cross_val_predict(dml_bias,␣
       ↪dml_train_nonlin[dml_x], dml_train_nonlin[dml_t], cv=5),
                                          dep_res = dml_train_nonlin[dml_y] -
                                                  cross_val_predict(dml_noise,␣
       ↪dml_train_nonlin[dml_x], dml_train_nonlin[dml_y], cv=5))

      dml_nonlin = LGBMRegressor(max_depth=lgbm_max, min_child_samples=child,␣
       ↪learning_rate =learn_rate, random_state=random_st)
```

```
[LightGBM] [Info] Auto-choosing col-wise multi-threading, the overhead of
testing was 0.002708 seconds.
You can set `force_col_wise=true` to remove the overhead.
[LightGBM] [Info] Total Bins 2570
[LightGBM] [Info] Number of data points in the train set: 39684, number of used
features: 13
[LightGBM] [Info] Start training from score 0.499345
[LightGBM] [Warning] No further splits with positive gain, best gain: -inf
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[LightGBM] [Info] Auto-choosing col-wise multi-threading, the overhead of
testing was 0.002795 seconds.
You can set `force_col_wise=true` to remove the overhead.
[LightGBM] [Info] Total Bins 2569
[LightGBM] [Info] Number of data points in the train set: 39684, number of used
features: 13
[LightGBM] [Info] Start training from score 0.500630
[LightGBM] [Warning] No further splits with positive gain, best gain: -inf
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[LightGBM] [Info] Auto-choosing col-wise multi-threading, the overhead of
testing was 0.002731 seconds.
You can set `force_col_wise=true` to remove the overhead.
[LightGBM] [Info] Total Bins 2573
[LightGBM] [Info] Number of data points in the train set: 39684, number of used
features: 13
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[LightGBM] [Info] Start training from score 0.498286
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[LightGBM] [Info] Auto-choosing col-wise multi-threading, the overhead of
testing was 0.002761 seconds.
You can set `force_col_wise=true` to remove the overhead.
[LightGBM] [Info] Total Bins 2575
[LightGBM] [Info] Number of data points in the train set: 39684, number of used
features: 13
[LightGBM] [Info] Start training from score 0.499471
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[LightGBM] [Info] Auto-choosing col-wise multi-threading, the overhead of
testing was 0.002732 seconds.
You can set `force_col_wise=true` to remove the overhead.
[LightGBM] [Info] Total Bins 2574
[LightGBM] [Info] Number of data points in the train set: 39684, number of used
features: 13
[LightGBM] [Info] Start training from score 0.498690
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[LightGBM] [Info] Auto-choosing col-wise multi-threading, the overhead of
testing was 0.002743 seconds.
You can set `force_col_wise=true` to remove the overhead.
[LightGBM] [Info] Total Bins 2570
[LightGBM] [Info] Number of data points in the train set: 39684, number of used
features: 13
[LightGBM] [Info] Start training from score 0.052616
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[LightGBM] [Info] Auto-choosing col-wise multi-threading, the overhead of
testing was 0.002757 seconds.
You can set `force_col_wise=true` to remove the overhead.
[LightGBM] [Info] Total Bins 2569
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features: 13
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[LightGBM] [Warning] No further splits with positive gain, best gain: -inf
[LightGBM] [Info] Auto-choosing col-wise multi-threading, the overhead of
testing was 0.002928 seconds.
You can set `force_col_wise=true` to remove the overhead.
[LightGBM] [Info] Total Bins 2573
[LightGBM] [Info] Number of data points in the train set: 39684, number of used
features: 13
[LightGBM] [Info] Start training from score 0.053573
[LightGBM] [Warning] No further splits with positive gain, best gain: -inf
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[LightGBM] [Warning] No further splits with positive gain, best gain: -inf
[LightGBM] [Info] Auto-choosing col-wise multi-threading, the overhead of
testing was 0.002708 seconds.
You can set `force_col_wise=true` to remove the overhead.
[LightGBM] [Info] Total Bins 2575
[LightGBM] [Info] Number of data points in the train set: 39684, number of used
features: 13
[LightGBM] [Info] Start training from score 0.052011
[LightGBM] [Warning] No further splits with positive gain, best gain: -inf
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[LightGBM] [Warning] No further splits with positive gain, best gain: -inf
[LightGBM] [Info] Auto-choosing col-wise multi-threading, the overhead of
testing was 0.003134 seconds.
You can set `force_col_wise=true` to remove the overhead.
[LightGBM] [Info] Total Bins 2574
[LightGBM] [Info] Number of data points in the train set: 39684, number of used
features: 13
[LightGBM] [Info] Start training from score 0.052943
[LightGBM] [Warning] No further splits with positive gain, best gain: -inf
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[82]:

```
dml_wgt = dml_train_pred_nonlin["exp_res"] ** 2

dml_y_st = (dml_train_pred_nonlin["dep_res"] / dml_train_pred_nonlin["exp_res"])

dml_nonlin.fit(X=dml_train_pred_nonlin[dml_x], y=dml_y_st,␣
 ↪sample_weight=dml_wgt);
```

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[LightGBM] [Info] Auto-choosing col-wise multi-threading, the overhead of
testing was 0.003390 seconds.
You can set `force_col_wise=true` to remove the overhead.
[LightGBM] [Info] Total Bins 2571
[LightGBM] [Info] Number of data points in the train set: 49605, number of used
features: 13
```

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[LightGBM] [Info] Start training from score 0.002750
[LightGBM] [Warning] No further splits with positive gain, best gain: -inf
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[LightGBM] [Warning] No further splits with positive gain, best gain: -inf
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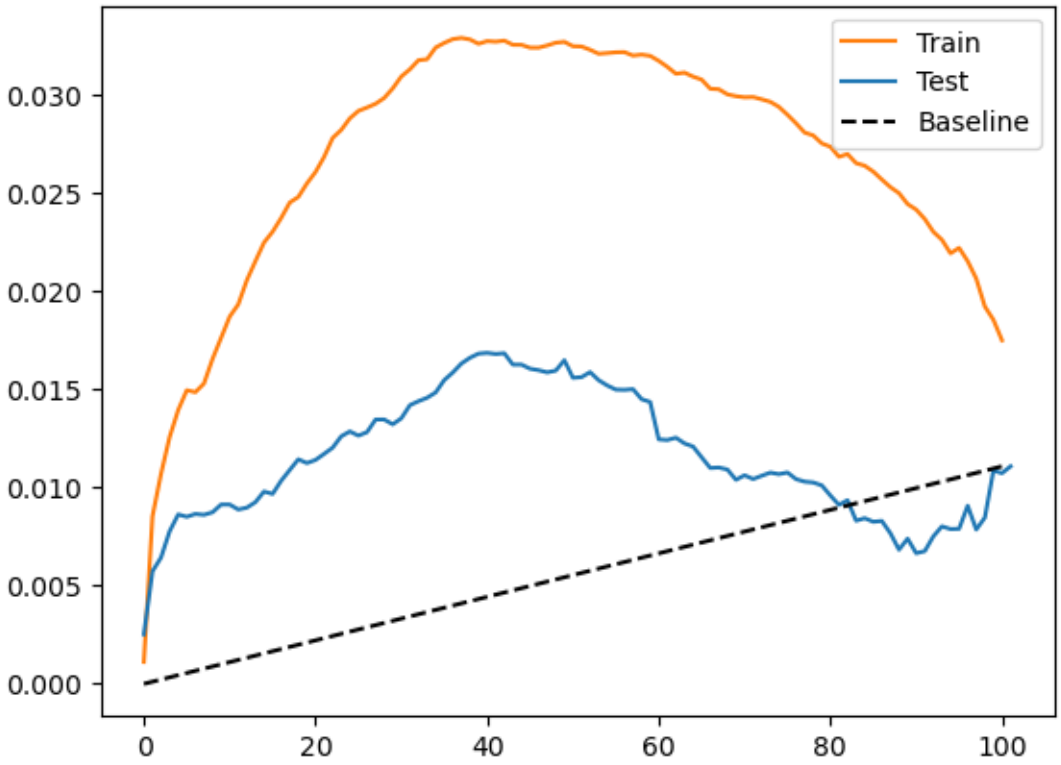
[83]:
```
dml_test_nonlin_cate = dml_test_nonlin.assign(dml_nonlin_cate=dml_nonlin.
 ↪predict(dml_test_nonlin[dml_x]))

dml_ate_nonlin = dml_test_nonlin_cate['dml_nonlin_cate'].mean()
print(dml_ate_nonlin)
```

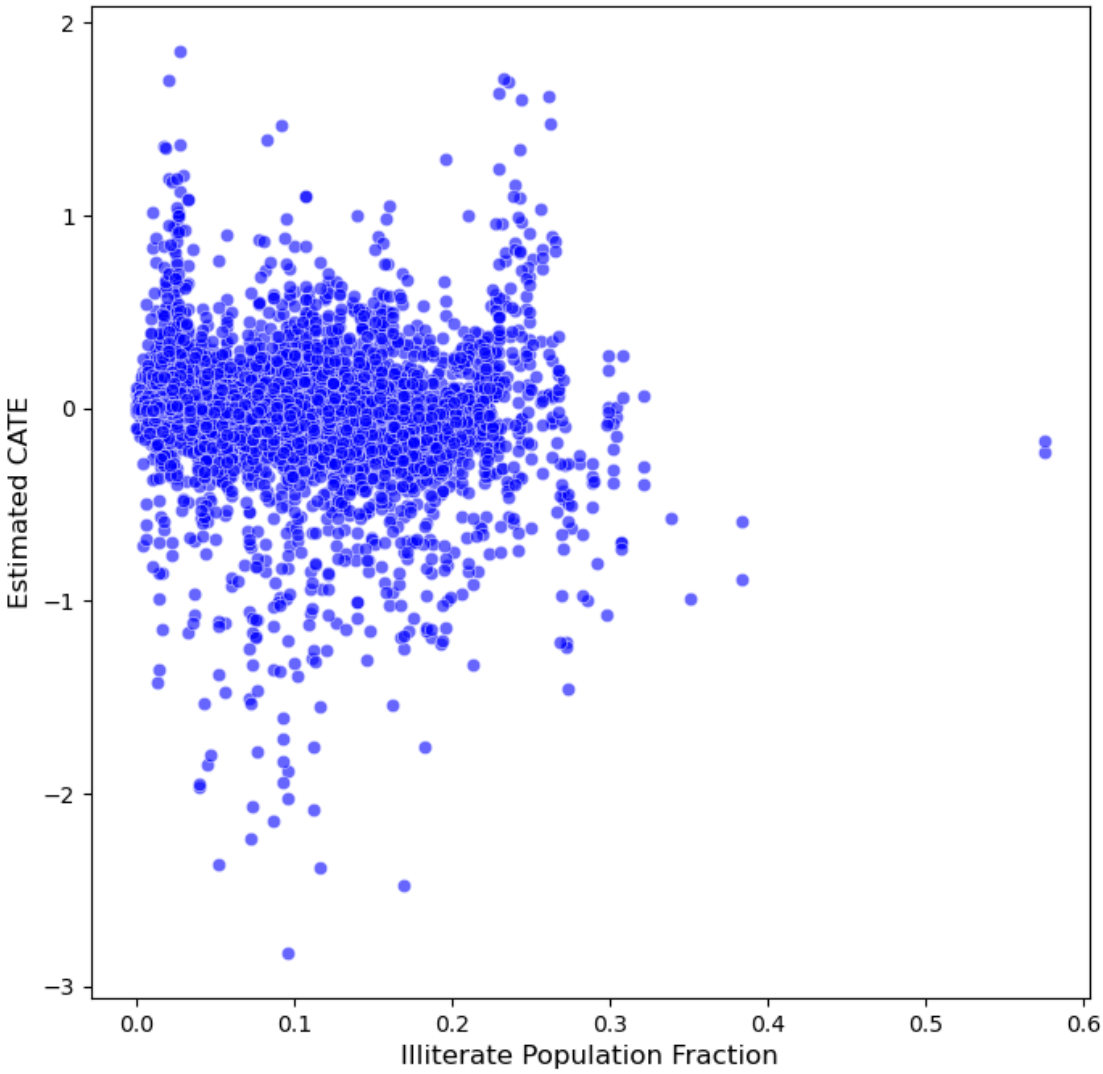
```
-0.006588459702133155
```

[84]:
```
gain_curve_train_non_param = cumulative_gain(dml_train_nonlin.
 ↪assign(dml_nonlin_cate=dml_nonlin.predict(dml_train_nonlin[dml_x])),
                                              "dml_nonlin_cate", y=dml_y,␣
 ↪t=dml_t)
gain_curve_test_non_param = cumulative_gain(dml_test_nonlin_cate,␣
 ↪"dml_nonlin_cate", y=dml_y, t=dml_t)
plt.plot(gain_curve_train_non_param, color="C1", label="Train")
plt.plot(gain_curve_test_non_param, color="C0", label="Test")
plt.plot([0, 100], [0, elast(dml_test, dml_y, dml_t)], linestyle="--",␣
 ↪color="black", label="Baseline")
plt.legend();
```



[85]:
```
plt.figure(figsize=(8, 8))
sns.scatterplot(data=dml_test_nonlin_cate, x='illit_share',␣
↪y='dml_nonlin_cate', color='blue', alpha=0.6)
plt.xlabel("Illiterate Population Fraction", fontsize =12)
plt.ylabel("Estimated CATE", fontsize =12)
```

[85]:
```
Text(0, 0.5, 'Estimated CATE')
```



[86]:
```
sim_dml_data = dml_data.copy()

sim_dml_data['illit_share'] = sim_dml_data['illit_share'].rank(pct=True)
sim_dml_x = sim_dml_data[list_x]
sim_dml_y = sim_dml_data['violence_episode_total']
sim_dml_x_train, sim_dml_x_test, sim_dml_y_train, sim_dml_y_test =␣
 ↪train_test_split(sim_dml_x, sim_dml_y, test_size=0.25,␣
 ↪random_state=random_st)
sim_dml_train = pd.concat([sim_dml_x_train, sim_dml_y_train], axis=1)
sim_dml_test = pd.concat([sim_dml_x_test, sim_dml_y_test], axis=1)
```

[87]:
```
dml_y = "violence_episode_total"
dml_t = "above_median1921"
```

```
dml_x =  controls_matching + [party for party in parties_1921 if party !=␣
 ↪'aggregated_share1921']

sim_dml_train_nonlin = sim_dml_train.copy()
sim_dml_test_nonlin = sim_dml_test.copy()

sim_dml_train_pred_nonlin = sim_dml_train_nonlin.assign(exp_res =
                                             sim_dml_train_nonlin[dml_t] -
                                             cross_val_predict(dml_bias,␣
 ↪sim_dml_train_nonlin[dml_x], sim_dml_train_nonlin[dml_t], cv=5),
                         dep_res = sim_dml_train_nonlin[dml_y] -
                                             cross_val_predict(dml_noise,␣
 ↪sim_dml_train_nonlin[dml_x], sim_dml_train_nonlin[dml_y], cv=5))

sim_dml_nonlin = LGBMRegressor(max_depth=lgbm_max, min_child_samples=child,␣
 ↪learning_rate =learn_rate, random_state=random_st)

sim_dml_wgt = sim_dml_train_pred_nonlin["exp_res"] ** 2

sim_dml_y_st = (sim_dml_train_pred_nonlin["dep_res"] /␣
 ↪sim_dml_train_pred_nonlin["exp_res"])

sim_dml_nonlin.fit(X=sim_dml_train_pred_nonlin[dml_x], y=sim_dml_y_st,␣
 ↪sample_weight=sim_dml_wgt);
```

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[LightGBM] [Info] Auto-choosing col-wise multi-threading, the overhead of
testing was 0.002805 seconds.
You can set `force_col_wise=true` to remove the overhead.
[LightGBM] [Info] Total Bins 2570
[LightGBM] [Info] Number of data points in the train set: 39684, number of used
features: 13
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testing was 0.004165 seconds.
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features: 13
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features: 13
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[LightGBM] [Info] Auto-choosing col-wise multi-threading, the overhead of
testing was 0.002730 seconds.
You can set `force_col_wise=true` to remove the overhead.
[LightGBM] [Info] Total Bins 2575
[LightGBM] [Info] Number of data points in the train set: 39684, number of used
features: 13
[LightGBM] [Info] Start training from score 0.499471
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[LightGBM] [Info] Auto-choosing col-wise multi-threading, the overhead of
testing was 0.002640 seconds.
You can set `force_col_wise=true` to remove the overhead.
[LightGBM] [Info] Total Bins 2574
[LightGBM] [Info] Number of data points in the train set: 39684, number of used
features: 13
[LightGBM] [Info] Start training from score 0.498690
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[LightGBM] [Warning] No further splits with positive gain, best gain: -inf
[LightGBM] [Info] Auto-choosing row-wise multi-threading, the overhead of
testing was 0.001204 seconds.
You can set `force_row_wise=true` to remove the overhead.
And if memory is not enough, you can set `force_col_wise=true`.
[LightGBM] [Info] Total Bins 2570
[LightGBM] [Info] Number of data points in the train set: 39684, number of used
features: 13
[LightGBM] [Info] Start training from score 0.052616
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[LightGBM] [Info] Auto-choosing col-wise multi-threading, the overhead of
testing was 0.002647 seconds.
You can set `force_col_wise=true` to remove the overhead.
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[LightGBM] [Info] Total Bins 2569
[LightGBM] [Info] Number of data points in the train set: 39684, number of used
features: 13
[LightGBM] [Info] Start training from score 0.052742
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[LightGBM] [Warning] No further splits with positive gain, best gain: -inf
[LightGBM] [Info] Auto-choosing col-wise multi-threading, the overhead of
testing was 0.002729 seconds.
You can set `force_col_wise=true` to remove the overhead.
[LightGBM] [Info] Total Bins 2573
[LightGBM] [Info] Number of data points in the train set: 39684, number of used
features: 13
[LightGBM] [Info] Start training from score 0.053573
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[LightGBM] [Info] Auto-choosing col-wise multi-threading, the overhead of
testing was 0.003002 seconds.
You can set `force_col_wise=true` to remove the overhead.
[LightGBM] [Info] Total Bins 2575
[LightGBM] [Info] Number of data points in the train set: 39684, number of used
features: 13
[LightGBM] [Info] Start training from score 0.052011
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[LightGBM] [Warning] No further splits with positive gain, best gain: -inf
[LightGBM] [Warning] No further splits with positive gain, best gain: -inf
[LightGBM] [Info] Auto-choosing col-wise multi-threading, the overhead of
testing was 0.002912 seconds.
You can set `force_col_wise=true` to remove the overhead.
[LightGBM] [Info] Total Bins 2574
[LightGBM] [Info] Number of data points in the train set: 39684, number of used
features: 13
[LightGBM] [Info] Start training from score 0.052943
[LightGBM] [Warning] No further splits with positive gain, best gain: -inf
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[LightGBM] [Info] Auto-choosing row-wise multi-threading, the overhead of
testing was 0.001061 seconds.
You can set `force_row_wise=true` to remove the overhead.
And if memory is not enough, you can set `force_col_wise=true`.
[LightGBM] [Info] Total Bins 2571
[LightGBM] [Info] Number of data points in the train set: 49605, number of used
features: 13
```

```
[LightGBM] [Info] Start training from score 0.003327
[LightGBM] [Warning] No further splits with positive gain, best gain: -inf
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```
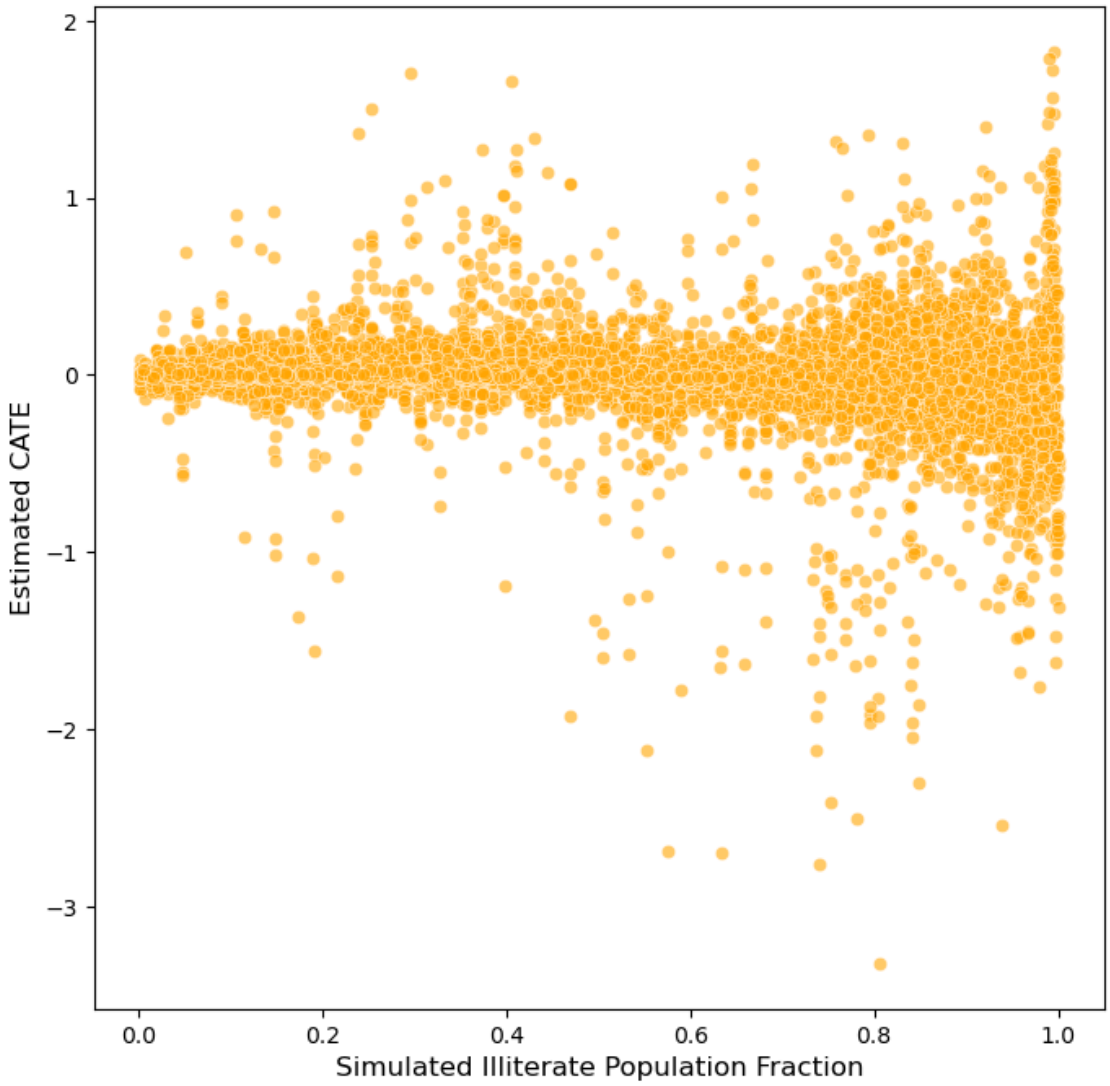

[88]:
```
sim_dml_test_nonlin_cate = sim_dml_test_nonlin.
 ↪assign(dml_nonlin_cate=sim_dml_nonlin.predict(sim_dml_test_nonlin[dml_x]))

sim_dml_ate_nonlin = sim_dml_test_nonlin_cate['dml_nonlin_cate'].mean()
print(sim_dml_ate_nonlin)
```

```
-0.0027249613912302953
```

[89]:
```
plt.figure(figsize=(8, 8))
sns.scatterplot(data=sim_dml_test_nonlin_cate, x='illit_share',␣
 ↪y='dml_nonlin_cate', color='orange', alpha=0.6)

plt.xlabel("Simulated Illiterate Population Fraction", fontsize = 12)
plt.ylabel("Estimated CATE", fontsize = 12)
```

[89]:
```
Text(0, 0.5, 'Estimated CATE')
```



[Model 12] Causal Forest

[90]:
```
hte_data = ml_data.copy()

controls_matching = ['avg_cloud_coverage', 'avg_rainfall_millimeter',␣
 ↪'avg_temperature',
                     'BBC_SNR_Ratio', 'popul_000s', 'female_share',␣
 ↪'illit_share']

all_x = controls_matching + [party for party in parties_1921 if party !=␣
 ↪'aggregated_share1921'] + ['above_median1921']
```

[91]:
```
hte_x = hte_data[all_x].values
hte_t = hte_data['above_median1921'].values.reshape(-1, 1)
hte_y = hte_data['violence_episode_total'].values.reshape(-1, 1)

hte_x_test = hte_x[:5000].copy()
hte_x_test[:, 0] = np.linspace(np.percentile(hte_x[:, 0], 1), np.
↪percentile(hte_x[:, 0], 99), 5000)
```

[92]:
```
treatment_model = LGBMRegressor(max_depth=3, random_state = random_st)
treatment_model.fit(hte_x, hte_t)
```

```
[LightGBM] [Info] Auto-choosing row-wise multi-threading, the overhead of
testing was 0.002099 seconds.
You can set `force_row_wise=true` to remove the overhead.
And if memory is not enough, you can set `force_col_wise=true`.
[LightGBM] [Info] Total Bins 2583
[LightGBM] [Info] Number of data points in the train set: 66141, number of used
features: 14
[LightGBM] [Info] Start training from score 0.499962
[LightGBM] [Warning] No further splits with positive gain, best gain: -inf
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```

```
A column-vector y was passed when a 1d array was expected. Please change the
shape of y to (n_samples, ), for example using ravel().
```

[92]:

```
LGBMRegressor(max_depth=3, random_state=55)
```

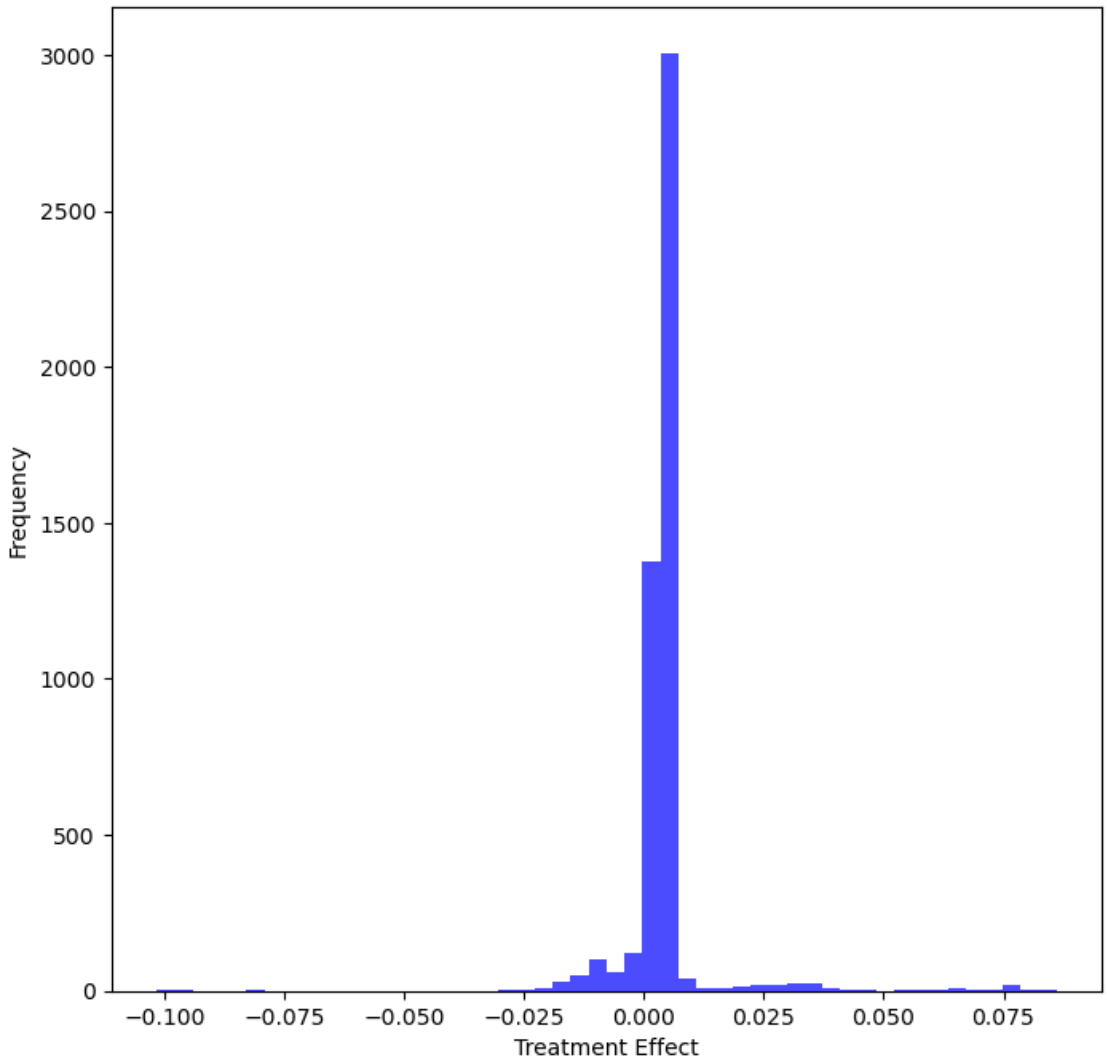
[95]:

```
est = CausalForest(criterion='het',
                   n_estimators=500,
                   min_samples_leaf=50,
                   min_balancedness_tol=.5,
                   max_depth=5,
                   max_samples=0.25,
                   inference=True,
                   fit_intercept=True,
                   subforest_size=5,
                   honest=True,
                   verbose=0,
                   n_jobs=-1,
                   random_state=88)


est.fit(hte_x, hte_t, hte_y)

avg, lower, upper = est.predict(hte_x_test, interval=True, alpha=0.05)
```

```
hte = est.predict(hte_x_test)
```

[96]:
```
plt.figure(figsize=(8, 8))
plt.hist(avg, bins=50, color='blue', alpha=0.7)
plt.xlabel('Treatment Effect')
plt.ylabel('Frequency')
```

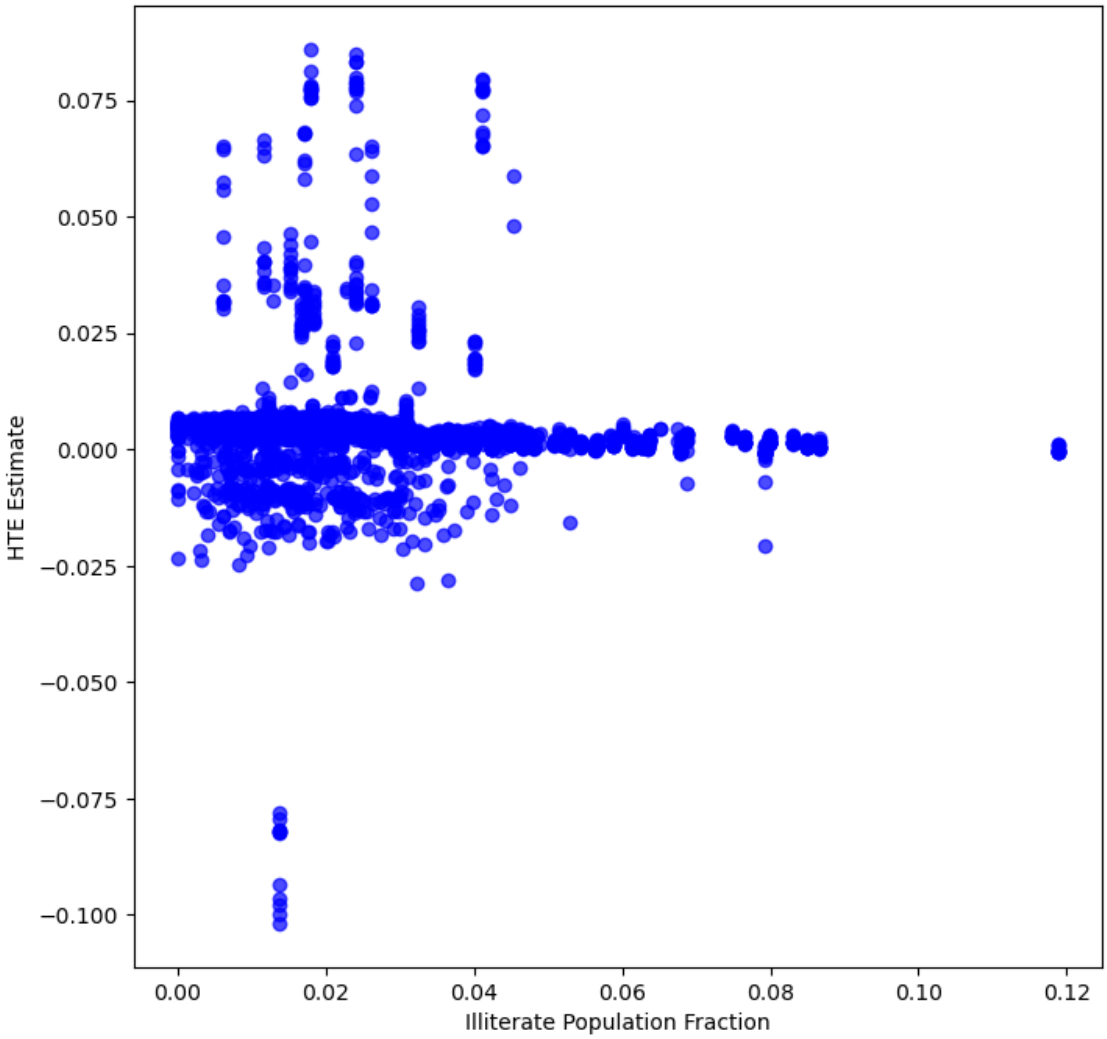
[96]:
```
Text(0, 0.5, 'Frequency')
```



[97]:
```
hte_illit = hte_x_test[:, all_x.index('illit_share')]

plt.figure(figsize=(8, 8))
```

```
plt.scatter(hte_illit[np.argsort(hte_illit)], hte[np.argsort(hte_illit)], alpha␣
 ↪= 0.7, color='blue')
plt.xlabel('Illiterate Population Fraction')
plt.ylabel('HTE Estimate')
```

[97]: Text(0, 0.5, 'HTE Estimate')



[98]:
```
hte_female = hte_x_test[:, all_x.index('female_share')]

plt.figure(figsize=(8, 8))
plt.scatter(hte_female[np.argsort(hte_female)], hte[np.argsort(hte_female)],␣
 ↪color='orange', alpha = 0.7)
plt.xlabel('Female Population Fraction')
plt.ylabel('HTE Estimate')
```

[98]: Text(0, 0.5, 'HTE Estimate')