Wang_Miaohan_HW3

February 9, 2020

```python
[1]: import random
     import numpy as np
     import matplotlib.pyplot as plt
     import pandas as pd
     from sklearn.datasets import make_regression
     from sklearn.model_selection import train_test_split
     from sklearn.metrics import mean_squared_error
     from sklearn.linear_model import LinearRegression
     from itertools import combinations
     from itertools import product
     from sklearn.linear_model import RidgeCV
     from sklearn.linear_model import LassoCV
     from sklearn.linear_model import ElasticNetCV
```

```python
[2]: def lm_arbitrary_subset(split_dataset, subset):
         X_train, X_test, y_train, y_test = split_dataset

         mod = LinearRegression()
         mod.fit(X_train[:,subset], y_train)
         MSE_train = mean_squared_error(y_train, mod.predict(X_train[:,subset]))
         MSE_test = mean_squared_error(y_test, mod.predict(X_test[:,subset]))

         return MSE_train, MSE_test, mod.coef_

     def best_selection_at_size(split_dataset, subset_size):

         min_MSE_train = 10000
         best_MSE_test = None
         best_subset = None
         best_coef = None

         for comb in combinations(range(20), subset_size):
             train, test, coef = lm_arbitrary_subset(split_dataset, comb)
             if train < min_MSE_train:
                 min_MSE_train = train
                 best_MSE_test = test
                 best_subset = comb
```

```
            best_coef = coef

    return min_MSE_train, best_MSE_test, best_subset, best_coef
```

Conceptual Exercises

Question 1

```
[3]: seed = 181205
     random.seed(seed)

     X_blob = make_regression(n_samples=1000, n_features=20, random_state=seed)[0]

     custom_beta = np.array([random.random()*10 for i in range(13)] +␣
      ↪[0,0,0,0,0,0,0])
     random.shuffle(custom_beta)


     y_response = np.matmul(X_blob, custom_beta) + np.random.normal(0,1,1000)

     split_dataset = train_test_split(X_blob, y_response,
                                      test_size=0.9,
                                      random_state=seed)
```

```
[4]: MSE_train_by_size = []
     MSE_test_by_size = []
     best_subset_by_size = []
     best_coef_by_size = []

     for i in range(1,21):
         MSE_train, MSE_test, subset, coef = best_selection_at_size(split_dataset, i)
         MSE_train_by_size.append(MSE_train)
         MSE_test_by_size.append(MSE_test)
         best_subset_by_size.append(subset)
         best_coef_by_size.append(coef)
```

```
[5]: concept_df = pd.DataFrame({'size': range(1,21),
                                'MSE_train': MSE_train_by_size,
                                'MSE_test': MSE_test_by_size,
                                'subset': best_subset_by_size,
                                'coef': best_coef_by_size})

     # dataframe entry with the lowest MSE_train value
     concept_df.sort_values(by='MSE_train').iloc[0]
```
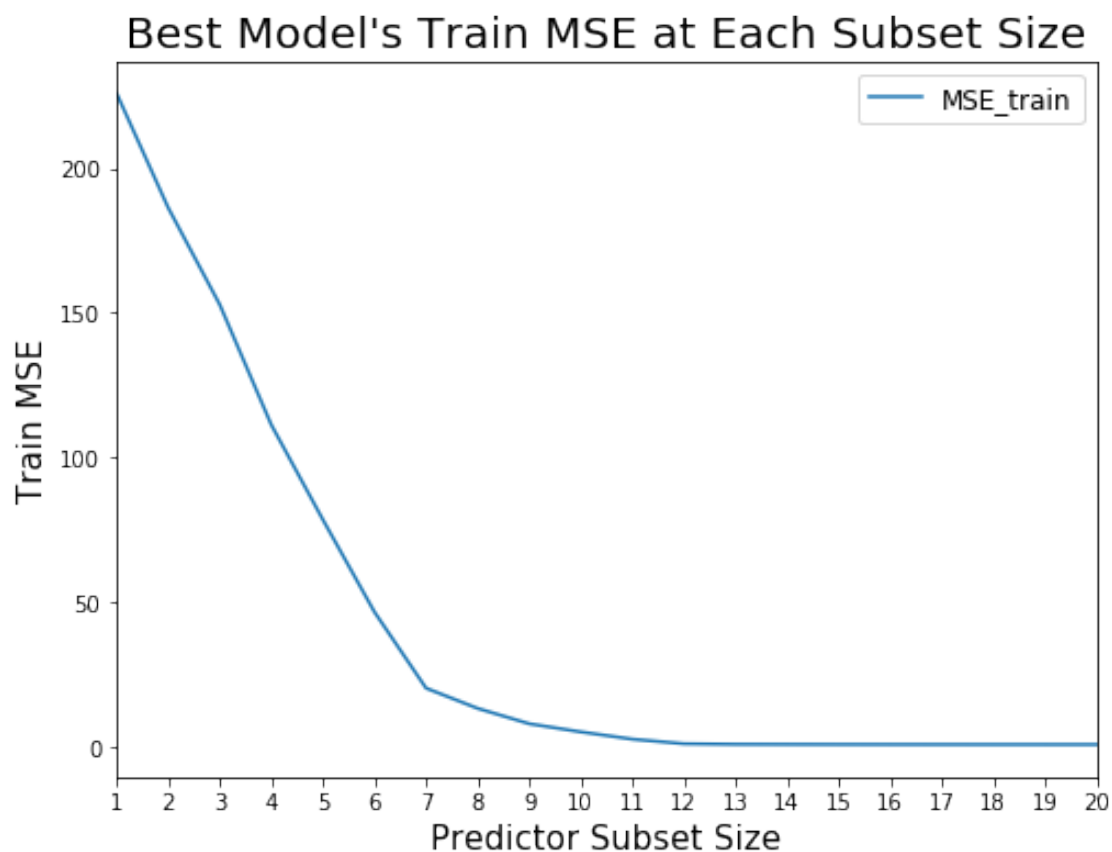
2

```
[5]: size                                                  20
     MSE_train                                        0.860451
     MSE_test                                          1.27396
     subset          (0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13,…
     coef            [0.07451255914758247, 0.010953166916894776, 0…
     Name: 19, dtype: object
```

```python
[6]: concept_df.plot(x='size', y='MSE_train', kind='line',
                      figsize=(8,6), xticks=range(1,21))
     plt.title("Best Model's Train MSE at Each Subset Size", fontsize=20)
     plt.xlabel('Predictor Subset Size', fontsize=15)
     plt.ylabel('Train MSE', fontsize=15)
     plt.legend(fontsize=12);
```
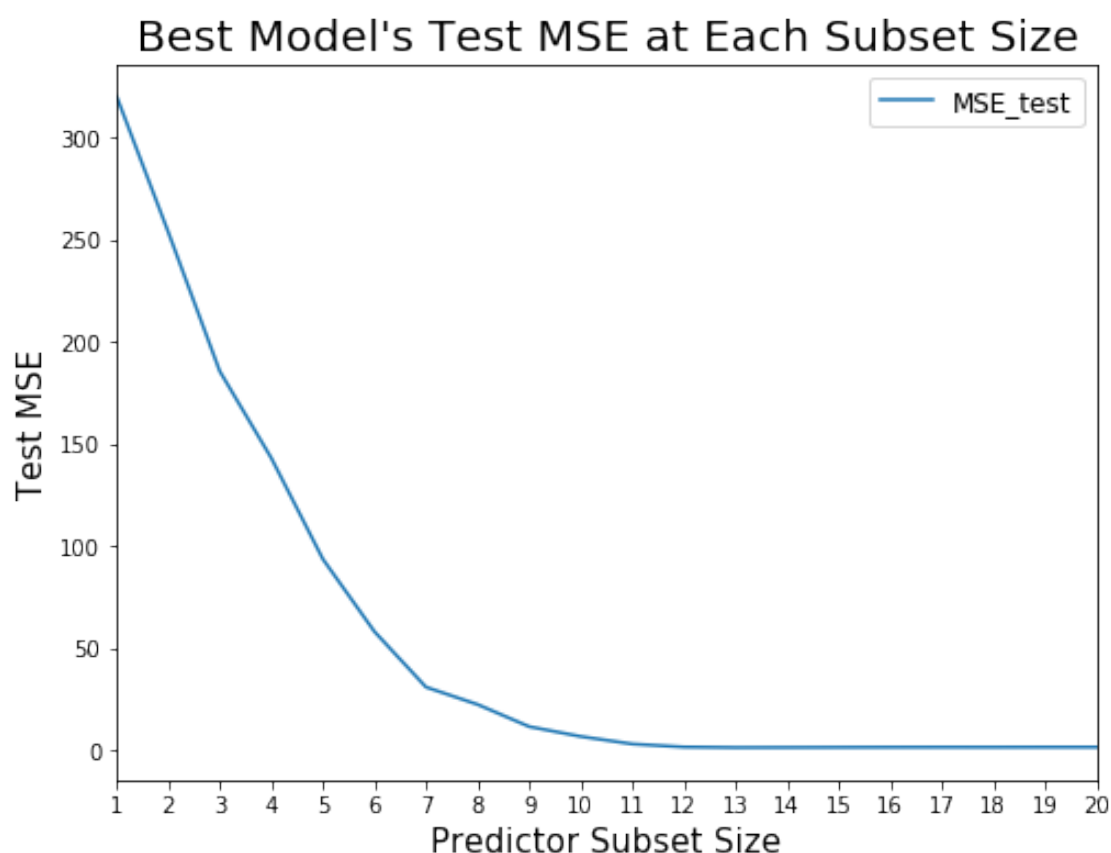

The model of subset size 20 has the minimum training MSE value.

```python
[7]: # dataframe entry with the lowest MSE_test value
     concept_df.sort_values(by='MSE_test').iloc[0]
```

```
[7]: size                                                              13
     MSE_train                                                  0.948883
     MSE_test                                                    1.08771
     subset          (3, 4, 5, 7, 8, 9, 10, 11, 12, 13, 16, 17, 18)
     coef          [5.091719932586949, 2.0897350311061285, 5.7893…
     Name: 12, dtype: object
```

```
[8]: concept_df.plot(x='size', y='MSE_test', kind='line',
                     figsize=(8,6), xticks=range(1,21))
     plt.title("Best Model's Test MSE at Each Subset Size", fontsize=20)
     plt.xlabel('Predictor Subset Size', fontsize=15)
     plt.ylabel('Test MSE', fontsize=15)
     plt.legend(fontsize=12);
```


The model of subset size 13 has the minimum testing MSE value. This shows that the model of subset size 20 overfitted the training data and have less predictive power over new datasets. Although model of subset size 13 does not have the lowest training MSE, it does have the best predictive power when facing new data. Also, this subset excludes all zero coefficients, which best predicts new (test) data.

```
[9]:  # positions of zero entries in custom_beta
      [i for i in range(20) if custom_beta[i] == 0]
```

```
[9]:  [0, 1, 2, 6, 14, 15, 19]
```

```
[10]:  # positions of parameters in the best model (subset size = 13)
       concept_df['subset'][12]
```

```
[10]:  (3, 4, 5, 7, 8, 9, 10, 11, 12, 13, 16, 17, 18)
```

The best model (coefficient size = 13) from the best subset selection closely resemble the model we used to generate the X data. This model excludes all zero entries we put into our generating β vector. Since the zero-entry features in X does not contribute anything to the true y we generated, the best model to predict the true y should only include the features that have some influence on the true y, hence the model with size 13.

```
[11]:  def formula_7(row):

           result = 0

           for i in range(row['size']):
               result += (row['coef'][i] - custom_beta[row['subset'][i]]) ** 2

           return np.sqrt(result)
```
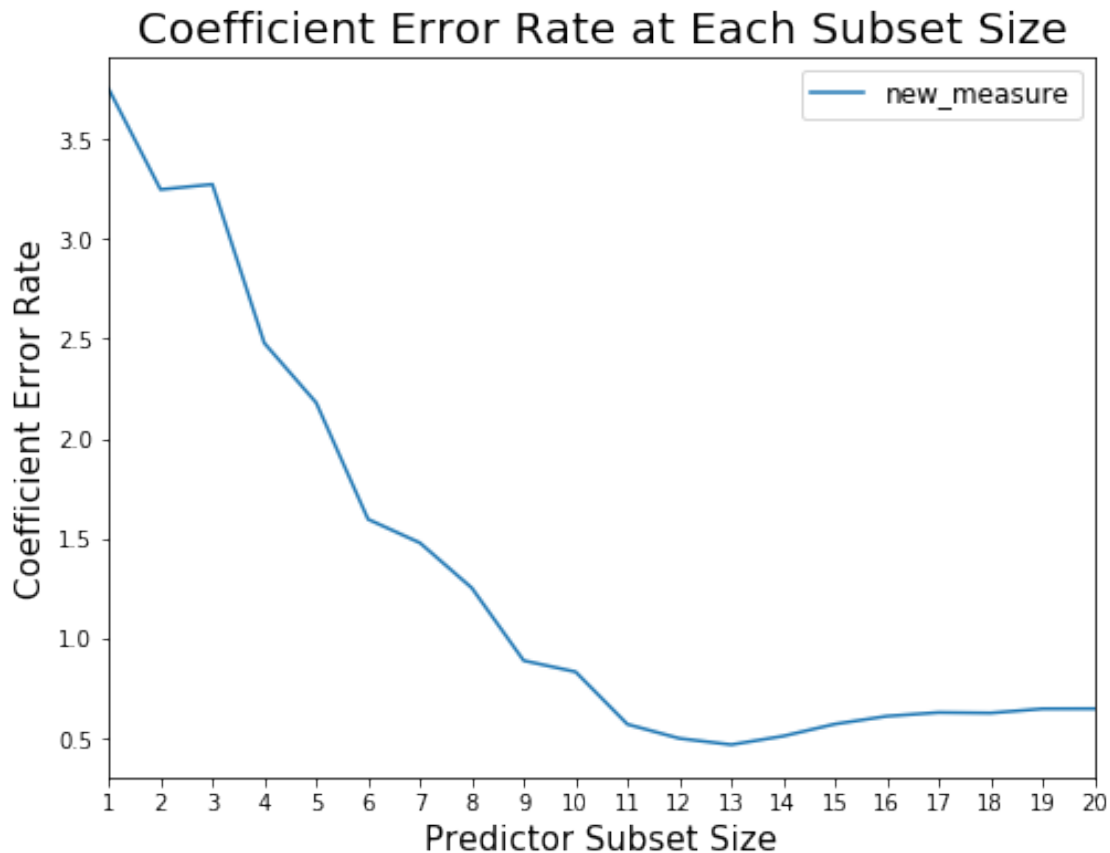
```
[12]:  concept_df['new_measure'] = concept_df.apply(formula_7, axis=1)

       concept_df.plot(x='size', y='new_measure', kind='line',
                       figsize=(8,6), xticks=range(1,21))
       plt.title("Coefficient Error Rate at Each Subset Size", fontsize=20)
       plt.xlabel('Predictor Subset Size', fontsize=15)
       plt.ylabel('Coefficient Error Rate', fontsize=15)
       plt.legend(fontsize=12);
```

Coefficient Error Rate at Each Subset Size

This plot is very close to the test MSE plot we obtained earlier, but with a minumum value at subset size 12. This might indicate that the model with the best test MSE does not necessarily have its coefficients closest to the true beta coefficients. The coefficients of the best test MSE model might have accounted further for the random errors occuring when we are generating the y data.

Application Exercises

```
[13]:  train_df = pd.read_csv('data/gss_train.csv')
       test_df = pd.read_csv('data/gss_test.csv')

       y_train = train_df['egalit_scale']
       X_train = train_df.drop('egalit_scale', axis=1)
       y_test = test_df['egalit_scale']
       X_test = test_df.drop('egalit_scale', axis=1)
```

Least Squares Linear Model

```
[14]: lslm_mod = LinearRegression().fit(X_train, y_train)
      lslm_MSE = mean_squared_error(y_test, lslm_mod.predict(X_test))
      print(f'The MSE of the least squares linear model is {lslm_MSE}.')
```

The MSE of the least squares linear model is 63.213629623014995.

Ridge Regression Model

```
[15]: ridge_mod = RidgeCV(cv=10).fit(X_train, y_train)
      ridge_MSE = mean_squared_error(y_test, ridge_mod.predict(X_test))
      print(f'The lambda chosen is {ridge_mod.alpha_}.')
      print(f'The MSE of the ridge regression model is {ridge_MSE}.')
```

The lambda chosen is 10.0.
The MSE of the ridge regression model is 62.49920243957809.

Lasso Regression Model

```
[16]: lasso_mod = LassoCV(cv=10).fit(X_train, y_train)
      lasso_MSE = mean_squared_error(y_test, lasso_mod.predict(X_test))
      non_zero_coef_lasso = [c for c in lasso_mod.coef_ if c != 0]
      print(f'The lambda chosen is {lasso_mod.alpha_}.')
      print(f'The MSE of the lasso regression model is {lasso_MSE}.')
      print(f'The number of nonzero coefficient estimates is␣
       ↪{len(non_zero_coef_lasso)}.')
```

The lambda chosen is 0.09991906177130906.
The MSE of the lasso regression model is 62.7780157899344.
The number of nonzero coefficient estimates is 24.

Elastic Net Regression Model

```
[17]: est_values = np.arange(0, 1.1, 0.1)

      el_mod = ElasticNetCV(l1_ratio=est_values, alphas=est_values,
                            cv=10, random_state=seed).fit(X_train, y_train)

      el_MSE = mean_squared_error(y_test, el_mod.predict(X_test))
```

/anaconda3/lib/python3.7/site-
packages/sklearn/linear_model/_coordinate_descent.py:472: UserWarning:
Coordinate descent with alpha=0 may lead to unexpected results and is
discouraged.

```
    tol, rng, random, positive)
/anaconda3/lib/python3.7/site-
packages/sklearn/linear_model/_coordinate_descent.py:472: ConvergenceWarning:
Objective did not converge. You might want to increase the number of iterations.
Duality gap: 46070.60730221004, tolerance: 12.395240465465465
    tol, rng, random, positive)
/anaconda3/lib/python3.7/site-
packages/sklearn/linear_model/_coordinate_descent.py:472: UserWarning:
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/anaconda3/lib/python3.7/site-
packages/sklearn/linear_model/_coordinate_descent.py:472: ConvergenceWarning:
Objective did not converge. You might want to increase the number of iterations.
Duality gap: 45686.31123851805, tolerance: 12.395240465465465
    tol, rng, random, positive)
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packages/sklearn/linear_model/_coordinate_descent.py:472: UserWarning:
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    tol, rng, random, positive)
/anaconda3/lib/python3.7/site-
packages/sklearn/linear_model/_coordinate_descent.py:472: ConvergenceWarning:
Objective did not converge. You might want to increase the number of iterations.
Duality gap: 45265.60715033991, tolerance: 12.395240465465465
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/anaconda3/lib/python3.7/site-
packages/sklearn/linear_model/_coordinate_descent.py:472: UserWarning:
Coordinate descent with alpha=0 may lead to unexpected results and is
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    tol, rng, random, positive)
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packages/sklearn/linear_model/_coordinate_descent.py:472: ConvergenceWarning:
Objective did not converge. You might want to increase the number of iterations.
Duality gap: 44800.809950793846, tolerance: 12.395240465465465
    tol, rng, random, positive)
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packages/sklearn/linear_model/_coordinate_descent.py:472: UserWarning:
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    tol, rng, random, positive)
/anaconda3/lib/python3.7/site-
packages/sklearn/linear_model/_coordinate_descent.py:472: ConvergenceWarning:
Objective did not converge. You might want to increase the number of iterations.
Duality gap: 44281.18238840165, tolerance: 12.395240465465465
    tol, rng, random, positive)
/anaconda3/lib/python3.7/site-
packages/sklearn/linear_model/_coordinate_descent.py:472: UserWarning:
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Coordinate descent with alpha=0 may lead to unexpected results and is
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  tol, rng, random, positive)
/anaconda3/lib/python3.7/site-
packages/sklearn/linear_model/_coordinate_descent.py:472: ConvergenceWarning:
Objective did not converge. You might want to increase the number of iterations.
Duality gap: 43690.94265936535, tolerance: 12.395240465465465
  tol, rng, random, positive)
/anaconda3/lib/python3.7/site-
packages/sklearn/linear_model/_coordinate_descent.py:472: UserWarning:
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  tol, rng, random, positive)
/anaconda3/lib/python3.7/site-
packages/sklearn/linear_model/_coordinate_descent.py:472: ConvergenceWarning:
Objective did not converge. You might want to increase the number of iterations.
Duality gap: 43005.302990744705, tolerance: 12.395240465465465
  tol, rng, random, positive)
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packages/sklearn/linear_model/_coordinate_descent.py:472: UserWarning:
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  tol, rng, random, positive)
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packages/sklearn/linear_model/_coordinate_descent.py:472: ConvergenceWarning:
Objective did not converge. You might want to increase the number of iterations.
Duality gap: 42181.64906125942, tolerance: 12.395240465465465
  tol, rng, random, positive)
/anaconda3/lib/python3.7/site-
packages/sklearn/linear_model/_coordinate_descent.py:472: UserWarning:
Coordinate descent with alpha=0 may lead to unexpected results and is
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  tol, rng, random, positive)
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packages/sklearn/linear_model/_coordinate_descent.py:472: ConvergenceWarning:
Objective did not converge. You might want to increase the number of iterations.
Duality gap: 41136.41678843817, tolerance: 12.395240465465465
  tol, rng, random, positive)
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packages/sklearn/linear_model/_coordinate_descent.py:472: UserWarning:
Coordinate descent with alpha=0 may lead to unexpected results and is
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  tol, rng, random, positive)
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packages/sklearn/linear_model/_coordinate_descent.py:472: ConvergenceWarning:
Objective did not converge. You might want to increase the number of iterations.
Duality gap: 39665.39728364625, tolerance: 12.395240465465465
  tol, rng, random, positive)
```

```
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packages/sklearn/linear_model/_coordinate_descent.py:472: UserWarning:
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packages/sklearn/linear_model/_coordinate_descent.py:472: ConvergenceWarning:
Objective did not converge. You might want to increase the number of iterations.
Duality gap: 36707.79896221639, tolerance: 12.395240465465465
  tol, rng, random, positive)
/anaconda3/lib/python3.7/site-
packages/sklearn/linear_model/_coordinate_descent.py:472: UserWarning:
Coordinate descent with alpha=0 may lead to unexpected results and is
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  tol, rng, random, positive)
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packages/sklearn/linear_model/_coordinate_descent.py:472: ConvergenceWarning:
Objective did not converge. You might want to increase the number of iterations.
Duality gap: 46388.81788509128, tolerance: 12.501906826706676
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packages/sklearn/linear_model/_coordinate_descent.py:472: UserWarning:
Coordinate descent with alpha=0 may lead to unexpected results and is
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  tol, rng, random, positive)
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packages/sklearn/linear_model/_coordinate_descent.py:472: ConvergenceWarning:
Objective did not converge. You might want to increase the number of iterations.
Duality gap: 46001.68505385365, tolerance: 12.501906826706676
  tol, rng, random, positive)
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packages/sklearn/linear_model/_coordinate_descent.py:472: UserWarning:
Coordinate descent with alpha=0 may lead to unexpected results and is
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packages/sklearn/linear_model/_coordinate_descent.py:472: ConvergenceWarning:
Objective did not converge. You might want to increase the number of iterations.
Duality gap: 45577.07738881578, tolerance: 12.501906826706676
  tol, rng, random, positive)
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packages/sklearn/linear_model/_coordinate_descent.py:472: UserWarning:
Coordinate descent with alpha=0 may lead to unexpected results and is
discouraged.
  tol, rng, random, positive)
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packages/sklearn/linear_model/_coordinate_descent.py:472: ConvergenceWarning:
Objective did not converge. You might want to increase the number of iterations.
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Duality gap: 45106.922666156766, tolerance: 12.501906826706676
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Coordinate descent with alpha=0 may lead to unexpected results and is
discouraged.
  tol, rng, random, positive)
/anaconda3/lib/python3.7/site-
packages/sklearn/linear_model/_coordinate_descent.py:472: ConvergenceWarning:
Objective did not converge. You might want to increase the number of iterations.
Duality gap: 44579.89783283268, tolerance: 12.501906826706676
  tol, rng, random, positive)
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packages/sklearn/linear_model/_coordinate_descent.py:472: UserWarning:
Coordinate descent with alpha=0 may lead to unexpected results and is
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Objective did not converge. You might want to increase the number of iterations.
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Coordinate descent with alpha=0 may lead to unexpected results and is
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packages/sklearn/linear_model/_coordinate_descent.py:472: ConvergenceWarning:
Objective did not converge. You might want to increase the number of iterations.
Duality gap: 43278.73230041752, tolerance: 12.501906826706676
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Objective did not converge. You might want to increase the number of iterations.
Duality gap: 42432.65913796097, tolerance: 12.501906826706676
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Coordinate descent with alpha=0 may lead to unexpected results and is
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packages/sklearn/linear_model/_coordinate_descent.py:472: ConvergenceWarning:
Objective did not converge. You might want to increase the number of iterations.
Duality gap: 41351.10329796778, tolerance: 12.501906826706676
  tol, rng, random, positive)
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packages/sklearn/linear_model/_coordinate_descent.py:472: UserWarning:
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packages/sklearn/linear_model/_coordinate_descent.py:472: ConvergenceWarning:
Objective did not converge. You might want to increase the number of iterations.
Duality gap: 39811.54926880444, tolerance: 12.501906826706676
  tol, rng, random, positive)
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packages/sklearn/linear_model/_coordinate_descent.py:472: UserWarning:
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packages/sklearn/linear_model/_coordinate_descent.py:472: ConvergenceWarning:
Objective did not converge. You might want to increase the number of iterations.
Duality gap: 36643.57130095476, tolerance: 12.501906826706676
  tol, rng, random, positive)
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packages/sklearn/linear_model/_coordinate_descent.py:472: UserWarning:
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packages/sklearn/linear_model/_coordinate_descent.py:472: ConvergenceWarning:
Objective did not converge. You might want to increase the number of iterations.
Duality gap: 45847.16414334598, tolerance: 12.28351822955739
  tol, rng, random, positive)
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packages/sklearn/linear_model/_coordinate_descent.py:472: UserWarning:
Coordinate descent with alpha=0 may lead to unexpected results and is
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  tol, rng, random, positive)
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packages/sklearn/linear_model/_coordinate_descent.py:472: ConvergenceWarning:
Objective did not converge. You might want to increase the number of iterations.
Duality gap: 45466.18739464188, tolerance: 12.28351822955739
  tol, rng, random, positive)
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packages/sklearn/linear_model/_coordinate_descent.py:472: UserWarning:
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packages/sklearn/linear_model/_coordinate_descent.py:472: ConvergenceWarning:
Objective did not converge. You might want to increase the number of iterations.
Duality gap: 45048.889510918474, tolerance: 12.28351822955739
  tol, rng, random, positive)
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packages/sklearn/linear_model/_coordinate_descent.py:472: UserWarning:
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  tol, rng, random, positive)
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packages/sklearn/linear_model/_coordinate_descent.py:472: ConvergenceWarning:
Objective did not converge. You might want to increase the number of iterations.
Duality gap: 44587.500004911984, tolerance: 12.28351822955739
  tol, rng, random, positive)
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packages/sklearn/linear_model/_coordinate_descent.py:472: UserWarning:
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packages/sklearn/linear_model/_coordinate_descent.py:472: ConvergenceWarning:
Objective did not converge. You might want to increase the number of iterations.
Duality gap: 44071.140563983085, tolerance: 12.28351822955739
  tol, rng, random, positive)
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packages/sklearn/linear_model/_coordinate_descent.py:472: ConvergenceWarning:
Objective did not converge. You might want to increase the number of iterations.
Duality gap: 43483.8045586722, tolerance: 12.28351822955739
  tol, rng, random, positive)
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/anaconda3/lib/python3.7/site-
packages/sklearn/linear_model/_coordinate_descent.py:472: ConvergenceWarning:
Objective did not converge. You might want to increase the number of iterations.
Duality gap: 42800.36347825122, tolerance: 12.28351822955739
  tol, rng, random, positive)
/anaconda3/lib/python3.7/site-
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Coordinate descent with alpha=0 may lead to unexpected results and is
discouraged.
  tol, rng, random, positive)
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Objective did not converge. You might want to increase the number of iterations.
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Objective did not converge. You might want to increase the number of iterations.
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  tol, rng, random, positive)
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Coordinate descent with alpha=0 may lead to unexpected results and is
discouraged.
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Coordinate descent with alpha=0 may lead to unexpected results and is
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Coordinate descent with alpha=0 may lead to unexpected results and is
discouraged.
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  tol, rng, random, positive)
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/anaconda3/lib/python3.7/site-
packages/sklearn/linear_model/_coordinate_descent.py:472: ConvergenceWarning:
Objective did not converge. You might want to increase the number of iterations.
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/anaconda3/lib/python3.7/site-
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Coordinate descent with alpha=0 may lead to unexpected results and is
discouraged.
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Objective did not converge. You might want to increase the number of iterations.
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Objective did not converge. You might want to increase the number of iterations.
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Objective did not converge. You might want to increase the number of iterations.
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Objective did not converge. You might want to increase the number of iterations.
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Objective did not converge. You might want to increase the number of iterations.
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/anaconda3/lib/python3.7/site-
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Objective did not converge. You might want to increase the number of iterations.
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Objective did not converge. You might want to increase the number of iterations.
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Objective did not converge. You might want to increase the number of iterations.
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Coordinate descent with alpha=0 may lead to unexpected results and is
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  tol, rng, random, positive)
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Objective did not converge. You might want to increase the number of iterations.
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Objective did not converge. You might want to increase the number of iterations.
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Coordinate descent with alpha=0 may lead to unexpected results and is
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Objective did not converge. You might want to increase the number of iterations.
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Coordinate descent with alpha=0 may lead to unexpected results and is
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Objective did not converge. You might want to increase the number of iterations.
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Duality gap: 36707.79896221681, tolerance: 12.395240465465465
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  tol, rng, random, positive)
/anaconda3/lib/python3.7/site-
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Objective did not converge. You might want to increase the number of iterations.
Duality gap: 36066.44710004874, tolerance: 12.300672318079519
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Objective did not converge. You might want to increase the number of iterations.
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Objective did not converge. You might want to increase the number of iterations.
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  tol, rng, random, positive)
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Objective did not converge. You might want to increase the number of iterations.
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Objective did not converge. You might want to increase the number of iterations.
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  tol, rng, random, positive)
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Coordinate descent with alpha=0 may lead to unexpected results and is
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Objective did not converge. You might want to increase the number of iterations.
Duality gap: 36977.45386687047, tolerance: 12.41885041260315
  tol, rng, random, positive)
/anaconda3/lib/python3.7/site-
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Coordinate descent with alpha=0 may lead to unexpected results and is
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  tol, rng, random, positive)
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Objective did not converge. You might want to increase the number of iterations.
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Objective did not converge. You might want to increase the number of iterations.
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Objective did not converge. You might want to increase the number of iterations.
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Objective did not converge. You might want to increase the number of iterations.
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Duality gap: 36977.45386687039, tolerance: 12.41885041260315
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Objective did not converge. You might want to increase the number of iterations.
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Objective did not converge. You might want to increase the number of iterations.
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Objective did not converge. You might want to increase the number of iterations.
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/anaconda3/lib/python3.7/site-
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Objective did not converge. You might want to increase the number of iterations.
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Objective did not converge. You might want to increase the number of iterations.
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Objective did not converge. You might want to increase the number of iterations.
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    tol, rng, random, positive)
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Objective did not converge. You might want to increase the number of iterations.
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Objective did not converge. You might want to increase the number of iterations.
Duality gap: 36066.44710004875, tolerance: 12.300672318079519
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Objective did not converge. You might want to increase the number of iterations.
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Coordinate descent with alpha=0 may lead to unexpected results and is
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Objective did not converge. You might want to increase the number of iterations.
Duality gap: 36925.24976476494, tolerance: 12.506681020255064
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Objective did not converge. You might want to increase the number of iterations.
Duality gap: 36707.798962216824, tolerance: 12.395240465465465
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Objective did not converge. You might want to increase the number of iterations.
Duality gap: 36643.57130095474, tolerance: 12.501906826706676
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Objective did not converge. You might want to increase the number of iterations.
Duality gap: 36657.592109299214, tolerance: 12.28351822955739
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Objective did not converge. You might want to increase the number of iterations.
Duality gap: 34582.25667175856, tolerance: 12.047380195048763
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Objective did not converge. You might want to increase the number of iterations.
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Objective did not converge. You might want to increase the number of iterations.
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Objective did not converge. You might want to increase the number of iterations.
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Objective did not converge. You might want to increase the number of iterations.
Duality gap: 36544.01160679993, tolerance: 12.143343435858965
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Coordinate descent with alpha=0 may lead to unexpected results and is
discouraged.
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Objective did not converge. You might want to increase the number of iterations.
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discouraged.
  tol, rng, random, positive)
/anaconda3/lib/python3.7/site-
packages/sklearn/linear_model/_coordinate_descent.py:472: ConvergenceWarning:
Objective did not converge. You might want to increase the number of iterations.
Duality gap: 36643.571300954834, tolerance: 12.5019068266706676
  tol, rng, random, positive)
/anaconda3/lib/python3.7/site-
packages/sklearn/linear_model/_coordinate_descent.py:472: UserWarning:
Coordinate descent with alpha=0 may lead to unexpected results and is
discouraged.
  tol, rng, random, positive)
/anaconda3/lib/python3.7/site-
packages/sklearn/linear_model/_coordinate_descent.py:472: ConvergenceWarning:
Objective did not converge. You might want to increase the number of iterations.
Duality gap: 36657.592109299236, tolerance: 12.28351822955739
  tol, rng, random, positive)
/anaconda3/lib/python3.7/site-
packages/sklearn/linear_model/_coordinate_descent.py:472: UserWarning:
```

Coordinate descent with alpha=0 may lead to unexpected results and is
discouraged.
  tol, rng, random, positive)
/anaconda3/lib/python3.7/site-
packages/sklearn/linear_model/_coordinate_descent.py:472: ConvergenceWarning:
Objective did not converge. You might want to increase the number of iterations.
Duality gap: 36732.87058489199, tolerance: 12.346995798949736
  tol, rng, random, positive)
/anaconda3/lib/python3.7/site-
packages/sklearn/linear_model/_coordinate_descent.py:472: UserWarning:
Coordinate descent with alpha=0 may lead to unexpected results and is
discouraged.
  tol, rng, random, positive)
/anaconda3/lib/python3.7/site-
packages/sklearn/linear_model/_coordinate_descent.py:472: ConvergenceWarning:
Objective did not converge. You might want to increase the number of iterations.
Duality gap: 36977.4538668704, tolerance: 12.41885041260315
  tol, rng, random, positive)
/anaconda3/lib/python3.7/site-
packages/sklearn/linear_model/_coordinate_descent.py:472: UserWarning:
Coordinate descent with alpha=0 may lead to unexpected results and is
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  tol, rng, random, positive)
/anaconda3/lib/python3.7/site-
packages/sklearn/linear_model/_coordinate_descent.py:472: ConvergenceWarning:
Objective did not converge. You might want to increase the number of iterations.
Duality gap: 34582.25667175846, tolerance: 12.047380195048763
  tol, rng, random, positive)
/anaconda3/lib/python3.7/site-
packages/sklearn/linear_model/_coordinate_descent.py:472: UserWarning:
Coordinate descent with alpha=0 may lead to unexpected results and is
discouraged.
  tol, rng, random, positive)
/anaconda3/lib/python3.7/site-
packages/sklearn/linear_model/_coordinate_descent.py:472: ConvergenceWarning:
Objective did not converge. You might want to increase the number of iterations.
Duality gap: 36066.44710004881, tolerance: 12.300672318079519
  tol, rng, random, positive)
/anaconda3/lib/python3.7/site-
packages/sklearn/linear_model/_coordinate_descent.py:472: UserWarning:
Coordinate descent with alpha=0 may lead to unexpected results and is
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  tol, rng, random, positive)
/anaconda3/lib/python3.7/site-
packages/sklearn/linear_model/_coordinate_descent.py:472: ConvergenceWarning:
Objective did not converge. You might want to increase the number of iterations.
Duality gap: 36544.011606799955, tolerance: 12.143343435858965
  tol, rng, random, positive)

```
/anaconda3/lib/python3.7/site-
packages/sklearn/linear_model/_coordinate_descent.py:472: UserWarning:
Coordinate descent with alpha=0 may lead to unexpected results and is
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  tol, rng, random, positive)
/anaconda3/lib/python3.7/site-
packages/sklearn/linear_model/_coordinate_descent.py:472: ConvergenceWarning:
Objective did not converge. You might want to increase the number of iterations.
Duality gap: 37142.41069079557, tolerance: 12.340121830457614
  tol, rng, random, positive)
/anaconda3/lib/python3.7/site-
packages/sklearn/linear_model/_coordinate_descent.py:472: UserWarning:
Coordinate descent with alpha=0 may lead to unexpected results and is
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  tol, rng, random, positive)
/anaconda3/lib/python3.7/site-
packages/sklearn/linear_model/_coordinate_descent.py:472: ConvergenceWarning:
Objective did not converge. You might want to increase the number of iterations.
Duality gap: 36925.24976476484, tolerance: 12.506681020255064
  tol, rng, random, positive)
/anaconda3/lib/python3.7/site-
packages/sklearn/linear_model/_coordinate_descent.py:472: UserWarning:
Coordinate descent with alpha=0 may lead to unexpected results and is
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  tol, rng, random, positive)
/anaconda3/lib/python3.7/site-
packages/sklearn/linear_model/_coordinate_descent.py:472: ConvergenceWarning:
Objective did not converge. You might want to increase the number of iterations.
Duality gap: 36707.798962216664, tolerance: 12.395240465465465
  tol, rng, random, positive)
/anaconda3/lib/python3.7/site-
packages/sklearn/linear_model/_coordinate_descent.py:472: UserWarning:
Coordinate descent with alpha=0 may lead to unexpected results and is
discouraged.
  tol, rng, random, positive)
/anaconda3/lib/python3.7/site-
packages/sklearn/linear_model/_coordinate_descent.py:472: ConvergenceWarning:
Objective did not converge. You might want to increase the number of iterations.
Duality gap: 36643.571300954674, tolerance: 12.501906826706676
  tol, rng, random, positive)
/anaconda3/lib/python3.7/site-
packages/sklearn/linear_model/_coordinate_descent.py:472: UserWarning:
Coordinate descent with alpha=0 may lead to unexpected results and is
discouraged.
  tol, rng, random, positive)
/anaconda3/lib/python3.7/site-
packages/sklearn/linear_model/_coordinate_descent.py:472: ConvergenceWarning:
Objective did not converge. You might want to increase the number of iterations.
```

```
Duality gap: 36657.59210929922, tolerance: 12.28351822955739
  tol, rng, random, positive)
/anaconda3/lib/python3.7/site-
packages/sklearn/linear_model/_coordinate_descent.py:472: UserWarning:
Coordinate descent with alpha=0 may lead to unexpected results and is
discouraged.
  tol, rng, random, positive)
/anaconda3/lib/python3.7/site-
packages/sklearn/linear_model/_coordinate_descent.py:472: ConvergenceWarning:
Objective did not converge. You might want to increase the number of iterations.
Duality gap: 36732.87058489192, tolerance: 12.346995798949736
  tol, rng, random, positive)
/anaconda3/lib/python3.7/site-
packages/sklearn/linear_model/_coordinate_descent.py:472: UserWarning:
Coordinate descent with alpha=0 may lead to unexpected results and is
discouraged.
  tol, rng, random, positive)
/anaconda3/lib/python3.7/site-
packages/sklearn/linear_model/_coordinate_descent.py:472: ConvergenceWarning:
Objective did not converge. You might want to increase the number of iterations.
Duality gap: 36977.45386687045, tolerance: 12.41885041260315
  tol, rng, random, positive)
/anaconda3/lib/python3.7/site-
packages/sklearn/linear_model/_coordinate_descent.py:472: UserWarning:
Coordinate descent with alpha=0 may lead to unexpected results and is
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  tol, rng, random, positive)
/anaconda3/lib/python3.7/site-
packages/sklearn/linear_model/_coordinate_descent.py:472: ConvergenceWarning:
Objective did not converge. You might want to increase the number of iterations.
Duality gap: 34582.256671758456, tolerance: 12.047380195048763
  tol, rng, random, positive)
/anaconda3/lib/python3.7/site-
packages/sklearn/linear_model/_coordinate_descent.py:472: UserWarning:
Coordinate descent with alpha=0 may lead to unexpected results and is
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  tol, rng, random, positive)
/anaconda3/lib/python3.7/site-
packages/sklearn/linear_model/_coordinate_descent.py:472: ConvergenceWarning:
Objective did not converge. You might want to increase the number of iterations.
Duality gap: 36066.44710004883, tolerance: 12.300672318079519
  tol, rng, random, positive)
/anaconda3/lib/python3.7/site-
packages/sklearn/linear_model/_coordinate_descent.py:472: UserWarning:
Coordinate descent with alpha=0 may lead to unexpected results and is
discouraged.
  tol, rng, random, positive)
/anaconda3/lib/python3.7/site-
```

packages/sklearn/linear_model/_coordinate_descent.py:472: ConvergenceWarning:
Objective did not converge. You might want to increase the number of iterations.
Duality gap: 36544.011606799904, tolerance: 12.143343435858965
  tol, rng, random, positive)
/anaconda3/lib/python3.7/site-
packages/sklearn/linear_model/_coordinate_descent.py:472: UserWarning:
Coordinate descent with alpha=0 may lead to unexpected results and is
discouraged.
  tol, rng, random, positive)
/anaconda3/lib/python3.7/site-
packages/sklearn/linear_model/_coordinate_descent.py:472: ConvergenceWarning:
Objective did not converge. You might want to increase the number of iterations.
Duality gap: 37142.41069079559, tolerance: 12.340121830457614
  tol, rng, random, positive)
/anaconda3/lib/python3.7/site-
packages/sklearn/linear_model/_coordinate_descent.py:472: UserWarning:
Coordinate descent with alpha=0 may lead to unexpected results and is
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  tol, rng, random, positive)
/anaconda3/lib/python3.7/site-
packages/sklearn/linear_model/_coordinate_descent.py:472: ConvergenceWarning:
Objective did not converge. You might want to increase the number of iterations.
Duality gap: 36925.24976476493, tolerance: 12.506681020255064
  tol, rng, random, positive)
/anaconda3/lib/python3.7/site-
packages/sklearn/linear_model/_coordinate_descent.py:472: UserWarning:
Coordinate descent with alpha=0 may lead to unexpected results and is
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  tol, rng, random, positive)
/anaconda3/lib/python3.7/site-
packages/sklearn/linear_model/_coordinate_descent.py:472: ConvergenceWarning:
Objective did not converge. You might want to increase the number of iterations.
Duality gap: 36707.79896221652, tolerance: 12.395240465465465
  tol, rng, random, positive)
/anaconda3/lib/python3.7/site-
packages/sklearn/linear_model/_coordinate_descent.py:472: UserWarning:
Coordinate descent with alpha=0 may lead to unexpected results and is
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  tol, rng, random, positive)
/anaconda3/lib/python3.7/site-
packages/sklearn/linear_model/_coordinate_descent.py:472: ConvergenceWarning:
Objective did not converge. You might want to increase the number of iterations.
Duality gap: 36643.57130095472, tolerance: 12.501906826706676
  tol, rng, random, positive)
/anaconda3/lib/python3.7/site-
packages/sklearn/linear_model/_coordinate_descent.py:472: UserWarning:
Coordinate descent with alpha=0 may lead to unexpected results and is
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```
  tol, rng, random, positive)
/anaconda3/lib/python3.7/site-
packages/sklearn/linear_model/_coordinate_descent.py:472: ConvergenceWarning:
Objective did not converge. You might want to increase the number of iterations.
Duality gap: 36657.59210929931, tolerance: 12.28351822955739
  tol, rng, random, positive)
/anaconda3/lib/python3.7/site-
packages/sklearn/linear_model/_coordinate_descent.py:472: UserWarning:
Coordinate descent with alpha=0 may lead to unexpected results and is
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  tol, rng, random, positive)
/anaconda3/lib/python3.7/site-
packages/sklearn/linear_model/_coordinate_descent.py:472: ConvergenceWarning:
Objective did not converge. You might want to increase the number of iterations.
Duality gap: 36732.870584892014, tolerance: 12.346995798949736
  tol, rng, random, positive)
/anaconda3/lib/python3.7/site-
packages/sklearn/linear_model/_coordinate_descent.py:472: UserWarning:
Coordinate descent with alpha=0 may lead to unexpected results and is
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  tol, rng, random, positive)
/anaconda3/lib/python3.7/site-
packages/sklearn/linear_model/_coordinate_descent.py:472: ConvergenceWarning:
Objective did not converge. You might want to increase the number of iterations.
Duality gap: 36977.45386687038, tolerance: 12.41885041260315
  tol, rng, random, positive)
/anaconda3/lib/python3.7/site-
packages/sklearn/linear_model/_coordinate_descent.py:472: UserWarning:
Coordinate descent with alpha=0 may lead to unexpected results and is
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  tol, rng, random, positive)
/anaconda3/lib/python3.7/site-
packages/sklearn/linear_model/_coordinate_descent.py:472: ConvergenceWarning:
Objective did not converge. You might want to increase the number of iterations.
Duality gap: 34582.25667175853, tolerance: 12.047380195048763
  tol, rng, random, positive)
/anaconda3/lib/python3.7/site-
packages/sklearn/linear_model/_coordinate_descent.py:472: UserWarning:
Coordinate descent with alpha=0 may lead to unexpected results and is
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  tol, rng, random, positive)
/anaconda3/lib/python3.7/site-
packages/sklearn/linear_model/_coordinate_descent.py:472: ConvergenceWarning:
Objective did not converge. You might want to increase the number of iterations.
Duality gap: 36066.44710004867, tolerance: 12.300672318079519
  tol, rng, random, positive)
/anaconda3/lib/python3.7/site-
packages/sklearn/linear_model/_coordinate_descent.py:472: UserWarning:
```

```
Coordinate descent with alpha=0 may lead to unexpected results and is
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  tol, rng, random, positive)
/anaconda3/lib/python3.7/site-
packages/sklearn/linear_model/_coordinate_descent.py:472: ConvergenceWarning:
Objective did not converge. You might want to increase the number of iterations.
Duality gap: 36544.01160679992, tolerance: 12.143343435858965
  tol, rng, random, positive)
/anaconda3/lib/python3.7/site-
packages/sklearn/linear_model/_coordinate_descent.py:472: UserWarning:
Coordinate descent with alpha=0 may lead to unexpected results and is
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  tol, rng, random, positive)
/anaconda3/lib/python3.7/site-
packages/sklearn/linear_model/_coordinate_descent.py:472: ConvergenceWarning:
Objective did not converge. You might want to increase the number of iterations.
Duality gap: 37142.41069079556, tolerance: 12.340121830457614
  tol, rng, random, positive)
/anaconda3/lib/python3.7/site-
packages/sklearn/linear_model/_coordinate_descent.py:472: UserWarning:
Coordinate descent with alpha=0 may lead to unexpected results and is
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  tol, rng, random, positive)
/anaconda3/lib/python3.7/site-
packages/sklearn/linear_model/_coordinate_descent.py:472: ConvergenceWarning:
Objective did not converge. You might want to increase the number of iterations.
Duality gap: 36925.24976476501, tolerance: 12.506681020255064
  tol, rng, random, positive)
/anaconda3/lib/python3.7/site-
packages/sklearn/linear_model/_coordinate_descent.py:472: UserWarning:
Coordinate descent with alpha=0 may lead to unexpected results and is
discouraged.
  tol, rng, random, positive)
/anaconda3/lib/python3.7/site-
packages/sklearn/linear_model/_coordinate_descent.py:472: ConvergenceWarning:
Objective did not converge. You might want to increase the number of iterations.
Duality gap: 36707.79896221658, tolerance: 12.395240465465465
  tol, rng, random, positive)
/anaconda3/lib/python3.7/site-
packages/sklearn/linear_model/_coordinate_descent.py:472: UserWarning:
Coordinate descent with alpha=0 may lead to unexpected results and is
discouraged.
  tol, rng, random, positive)
/anaconda3/lib/python3.7/site-
packages/sklearn/linear_model/_coordinate_descent.py:472: ConvergenceWarning:
Objective did not converge. You might want to increase the number of iterations.
Duality gap: 36643.57130095471, tolerance: 12.501906826706676
  tol, rng, random, positive)
```

```
/anaconda3/lib/python3.7/site-
packages/sklearn/linear_model/_coordinate_descent.py:472: UserWarning:
Coordinate descent with alpha=0 may lead to unexpected results and is
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  tol, rng, random, positive)
/anaconda3/lib/python3.7/site-
packages/sklearn/linear_model/_coordinate_descent.py:472: ConvergenceWarning:
Objective did not converge. You might want to increase the number of iterations.
Duality gap: 36657.59210929921, tolerance: 12.28351822955739
  tol, rng, random, positive)
/anaconda3/lib/python3.7/site-
packages/sklearn/linear_model/_coordinate_descent.py:472: UserWarning:
Coordinate descent with alpha=0 may lead to unexpected results and is
discouraged.
  tol, rng, random, positive)
/anaconda3/lib/python3.7/site-
packages/sklearn/linear_model/_coordinate_descent.py:472: ConvergenceWarning:
Objective did not converge. You might want to increase the number of iterations.
Duality gap: 36732.87058489207, tolerance: 12.346995798949736
  tol, rng, random, positive)
/anaconda3/lib/python3.7/site-
packages/sklearn/linear_model/_coordinate_descent.py:472: UserWarning:
Coordinate descent with alpha=0 may lead to unexpected results and is
discouraged.
  tol, rng, random, positive)
/anaconda3/lib/python3.7/site-
packages/sklearn/linear_model/_coordinate_descent.py:472: ConvergenceWarning:
Objective did not converge. You might want to increase the number of iterations.
Duality gap: 36977.45386687042, tolerance: 12.41885041260315
  tol, rng, random, positive)
/anaconda3/lib/python3.7/site-
packages/sklearn/linear_model/_coordinate_descent.py:472: UserWarning:
Coordinate descent with alpha=0 may lead to unexpected results and is
discouraged.
  tol, rng, random, positive)
/anaconda3/lib/python3.7/site-
packages/sklearn/linear_model/_coordinate_descent.py:472: ConvergenceWarning:
Objective did not converge. You might want to increase the number of iterations.
Duality gap: 34582.25667175858, tolerance: 12.047380195048763
  tol, rng, random, positive)
/anaconda3/lib/python3.7/site-
packages/sklearn/linear_model/_coordinate_descent.py:472: UserWarning:
Coordinate descent with alpha=0 may lead to unexpected results and is
discouraged.
  tol, rng, random, positive)
/anaconda3/lib/python3.7/site-
packages/sklearn/linear_model/_coordinate_descent.py:472: ConvergenceWarning:
Objective did not converge. You might want to increase the number of iterations.
```

```
Duality gap: 36066.44710004883, tolerance: 12.300672318079519
  tol, rng, random, positive)
/anaconda3/lib/python3.7/site-
packages/sklearn/linear_model/_coordinate_descent.py:472: UserWarning:
Coordinate descent with alpha=0 may lead to unexpected results and is
discouraged.
  tol, rng, random, positive)
/anaconda3/lib/python3.7/site-
packages/sklearn/linear_model/_coordinate_descent.py:472: ConvergenceWarning:
Objective did not converge. You might want to increase the number of iterations.
Duality gap: 36544.01160679991, tolerance: 12.143343435858965
  tol, rng, random, positive)
/anaconda3/lib/python3.7/site-
packages/sklearn/linear_model/_coordinate_descent.py:472: UserWarning:
Coordinate descent with alpha=0 may lead to unexpected results and is
discouraged.
  tol, rng, random, positive)
/anaconda3/lib/python3.7/site-
packages/sklearn/linear_model/_coordinate_descent.py:472: ConvergenceWarning:
Objective did not converge. You might want to increase the number of iterations.
Duality gap: 37142.41069079552, tolerance: 12.340121830457614
  tol, rng, random, positive)
/anaconda3/lib/python3.7/site-
packages/sklearn/linear_model/_coordinate_descent.py:472: UserWarning:
Coordinate descent with alpha=0 may lead to unexpected results and is
discouraged.
  tol, rng, random, positive)
/anaconda3/lib/python3.7/site-
packages/sklearn/linear_model/_coordinate_descent.py:472: ConvergenceWarning:
Objective did not converge. You might want to increase the number of iterations.
Duality gap: 36925.24976476496, tolerance: 12.506681020255064
  tol, rng, random, positive)
```

```python
[18]: print(f'The lambda chosen by the 10-fold cross validation is {el_mod.alpha_}.')
      print(f'The alpha chosen by the 10-fold cross validation is {el_mod.l1_ratio_}.
       ↪')
      print(f'The test MSE of this Elastic Model is {el_MSE}.')
      print(f'The number of non-zero coefficient is {len([i for i in el_mod.coef_ if␣
       ↪i != 0])}.')
```

```
The lambda chosen by the 10-fold cross validation is 0.1.
The alpha chosen by the 10-fold cross validation is 1.0.
The test MSE of this Elastic Model is 62.77841555477391.
The number of non-zero coefficient is 24.
```

```python
[19]: # evaluate predictive accuracy
      test_df['egalit_scale'].describe()
```

```
[19]:  count    493.000000
       mean      19.113590
       std        9.515674
       min        1.000000
       25%       13.000000
       50%       19.000000
       75%       27.000000
       max       35.000000
       Name: egalit_scale, dtype: float64
```

We cannot very accurately predict the individual's egalitarianism since the MSE remains high (above 60) throughout all models we have tried. Given the egalitarianism scale ranges from 1 to 35, the MSE of 62 would mean that the error for each prediction is approximately $\pm$ 7.75, which is a large gap on the scale of individual egalitarianism. When we check for the R^2 of the models, we find that the models only explains less than 31% of variance in the test data. Hence the predictors we have individual egalitarianism is not sufficient for producing a good model, or the predictors possess non-linear relationships that our linear models cannot capture the change adequately.

```
[20]:  lslm_mod.score(X_test, y_test)
```

```
[20]:  0.30045854148317575
```

```
[21]:  ridge_mod.score(X_test, y_test), lasso_mod.score(X_test, y_test)
```

```
[21]:  (0.30836461232400536, 0.3052791780762746)
```

```
[22]:  el_mod.score(X_test, y_test)
```

```
[22]:  0.3052747541556651
```

```
[ ]:
```