

# AML\_Group\_Project\_Notebook\_v1

December 7, 2024

```
[16]: import pandas as pd
import numpy as np
import matplotlib.pyplot as plt
import seaborn as sns
from sklearn.preprocessing import OrdinalEncoder
from sklearn.model_selection import train_test_split, cross_val_score, GridSearchCV
from sklearn.preprocessing import StandardScaler
from sklearn.linear_model import LogisticRegression
from imblearn.over_sampling import SMOTE
from imblearn.under_sampling import RandomUnderSampler
from sklearn.metrics import classification_report, accuracy_score
```

```
[17]: df = pd.read_csv('diabetes_012_health_indicators_BRFSS2015.csv')
print(df)
```

	Diabetes_012	HighBP	HighChol	CholCheck	BMI	Smoker	Stroke	\
0	0.0	1.0	1.0	1.0	40.0	1.0	0.0	
1	0.0	0.0	0.0	0.0	25.0	1.0	0.0	
2	0.0	1.0	1.0	1.0	28.0	0.0	0.0	
3	0.0	1.0	0.0	1.0	27.0	0.0	0.0	
4	0.0	1.0	1.0	1.0	24.0	0.0	0.0	
...	...	...	...	...	...	...	...	
253675	0.0	1.0	1.0	1.0	45.0	0.0	0.0	
253676	2.0	1.0	1.0	1.0	18.0	0.0	0.0	
253677	0.0	0.0	0.0	1.0	28.0	0.0	0.0	
253678	0.0	1.0	0.0	1.0	23.0	0.0	0.0	
253679	2.0	1.0	1.0	1.0	25.0	0.0	0.0	

	HeartDiseaseorAttack	PhysActivity	Fruits	...	AnyHealthcare	\
0	0.0	0.0	0.0	...	1.0	
1	0.0	1.0	0.0	...	0.0	
2	0.0	0.0	1.0	...	1.0	
3	0.0	1.0	1.0	...	1.0	
4	0.0	1.0	1.0	...	1.0	
...	...	...	...	...	...	
253675	0.0	0.0	1.0	...	1.0	
253676	0.0	0.0	0.0	...	1.0	

```

253677          0.0      1.0      1.0 ...      1.0
253678          0.0      0.0      1.0 ...      1.0
253679          1.0      1.0      1.0 ...      1.0

NoDocbcCost  GenHlth  MentHlth  PhysHlth  DiffWalk  Sex  Age \
0            0.0      5.0     18.0      15.0      1.0  0.0  9.0
1            1.0      3.0      0.0       0.0      0.0  0.0  7.0
2            1.0      5.0     30.0      30.0      1.0  0.0  9.0
3            0.0      2.0      0.0       0.0      0.0  0.0 11.0
4            0.0      2.0      3.0       0.0      0.0  0.0 11.0
...
253675          ...    ...    ...
253676          ...    ...    ...
253677          ...    ...    ...
253678          ...    ...    ...
253679          ...    ...    ...

Education  Income
0          4.0      3.0
1          6.0      1.0
2          4.0      8.0
3          3.0      6.0
4          5.0      4.0
...
253675          ...    ...
253676          ...    ...
253677          ...    ...
253678          ...    ...
253679          ...    ...

```

[253680 rows x 22 columns]

[18]: df.shape

[18]: (253680, 22)

[19]: df.head()

```

[19]: Diabetes_012  HighBP  HighChol  CholCheck  BMI  Smoker  Stroke \
0          0.0      1.0      1.0      1.0  40.0      1.0      0.0
1          0.0      0.0      0.0      0.0  25.0      1.0      0.0
2          0.0      1.0      1.0      1.0  28.0      0.0      0.0
3          0.0      1.0      0.0      1.0  27.0      0.0      0.0
4          0.0      1.0      1.0      1.0  24.0      0.0      0.0

HeartDiseaseorAttack  PhysActivity  Fruits  ...  AnyHealthcare \
0                  0.0          0.0      0.0 ...          1.0
1                  0.0          1.0      0.0 ...          0.0

```

```

2          0.0      0.0    1.0 ...
3          0.0      1.0    1.0 ...
4          0.0      1.0    1.0 ...

NoDocbcCost  GenHlth  MentHlth  PhysHlth  DiffWalk  Sex   Age   Education \
0           0.0      5.0     18.0     15.0      1.0  0.0   9.0    4.0
1           1.0      3.0     0.0      0.0       0.0  0.0   7.0    6.0
2           1.0      5.0     30.0     30.0      1.0  0.0   9.0    4.0
3           0.0      2.0     0.0      0.0       0.0  0.0  11.0   3.0
4           0.0      2.0     3.0      0.0       0.0  0.0  11.0   5.0

Income
0     3.0
1     1.0
2     8.0
3     6.0
4     4.0

[5 rows x 22 columns]

```

```
[20]: df.dtypes
df.describe()
```

```
[20]: Diabetes_012      HighBP      HighChol      CholCheck \
count  253680.000000  253680.000000  253680.000000  253680.000000
mean   0.296921      0.429001      0.424121      0.962670
std    0.698160      0.494934      0.494210      0.189571
min   0.000000      0.000000      0.000000      0.000000
25%   0.000000      0.000000      0.000000      1.000000
50%   0.000000      0.000000      0.000000      1.000000
75%   0.000000      1.000000      1.000000      1.000000
max   2.000000      1.000000      1.000000      1.000000

          BMI      Smoker      Stroke  HeartDiseaseorAttack \
count  253680.000000  253680.000000  253680.000000  253680.000000
mean   28.382364     0.443169     0.040571     0.094186
std    6.608694     0.496761     0.197294     0.292087
min   12.000000     0.000000     0.000000     0.000000
25%   24.000000     0.000000     0.000000     0.000000
50%   27.000000     0.000000     0.000000     0.000000
75%   31.000000     1.000000     0.000000     0.000000
max   98.000000     1.000000     1.000000     1.000000

          PhysActivity      Fruits ... AnyHealthcare      NoDocbcCost \
count  253680.000000  253680.000000 ... 253680.000000  253680.000000
mean   0.756544        0.634256 ... 0.951053        0.084177
std    0.429169        0.481639 ... 0.215759        0.277654
```

min	0.000000	0.000000	...	0.000000	0.000000
25%	1.000000	0.000000	...	1.000000	0.000000
50%	1.000000	1.000000	...	1.000000	0.000000
75%	1.000000	1.000000	...	1.000000	0.000000
max	1.000000	1.000000	...	1.000000	1.000000
	GenHlth	MentHlth	PhysHlth	DiffWalk	\
count	253680.000000	253680.000000	253680.000000	253680.000000	
mean	2.511392	3.184772	4.242081	0.168224	
std	1.068477	7.412847	8.717951	0.374066	
min	1.000000	0.000000	0.000000	0.000000	
25%	2.000000	0.000000	0.000000	0.000000	
50%	2.000000	0.000000	0.000000	0.000000	
75%	3.000000	2.000000	3.000000	0.000000	
max	5.000000	30.000000	30.000000	1.000000	
	Sex	Age	Education	Income	
count	253680.000000	253680.000000	253680.000000	253680.000000	
mean	0.440342	8.032119	5.050434	6.053875	
std	0.496429	3.054220	0.985774	2.071148	
min	0.000000	1.000000	1.000000	1.000000	
25%	0.000000	6.000000	4.000000	5.000000	
50%	0.000000	8.000000	5.000000	7.000000	
75%	1.000000	10.000000	6.000000	8.000000	
max	1.000000	13.000000	6.000000	8.000000	

[8 rows x 22 columns]

[21]: df.isnull().sum()

[21]: Diabetes_012	0
HighBP	0
HighChol	0
CholCheck	0
BMI	0
Smoker	0
Stroke	0
HeartDiseaseorAttack	0
PhysActivity	0
Fruits	0
Veggies	0
HvyAlcoholConsump	0
AnyHealthcare	0
NoDocbcCost	0
GenHlth	0
MentHlth	0
PhysHlth	0

```
DiffWalk          0
Sex              0
Age              0
Education        0
Income           0
dtype: int64
```

```
[22]: df.rename(columns={'Diabetes_012': 'Diabetes'}, inplace=True)

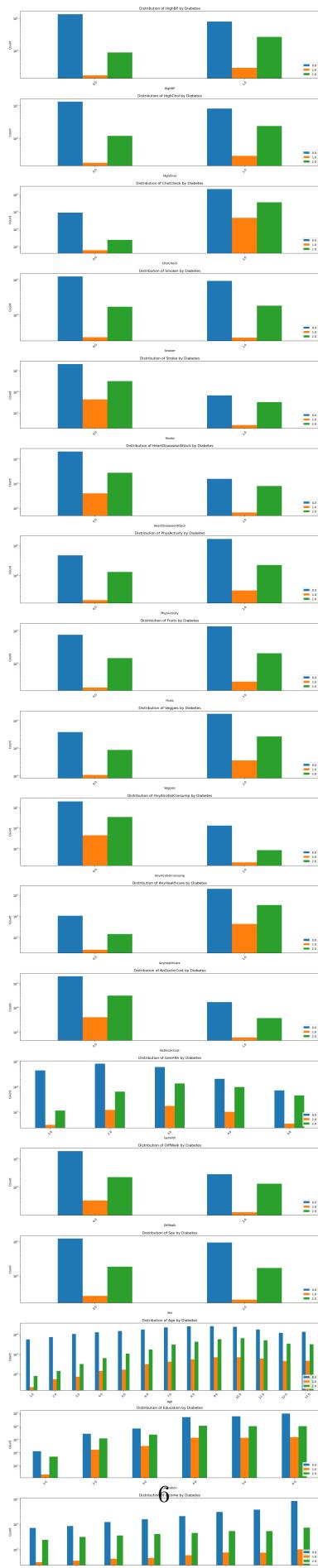
categorical_features = ['HighBP', 'HighChol', 'CholCheck', 'Smoker', 'Stroke',
                        'HeartDiseaseorAttack', 'PhysActivity', 'Fruits', 'Veggies',
                        'HvyAlcoholConsump', 'AnyHealthcare', 'NoDocbcCost', 'GenHlth', 'DiffWalk',
                        'Sex', 'Age', 'Education', 'Income']

plt.figure(figsize = (15,75))

for i, feature in enumerate(categorical_features):
    plt.subplot(len(categorical_features), 1, i + 1)

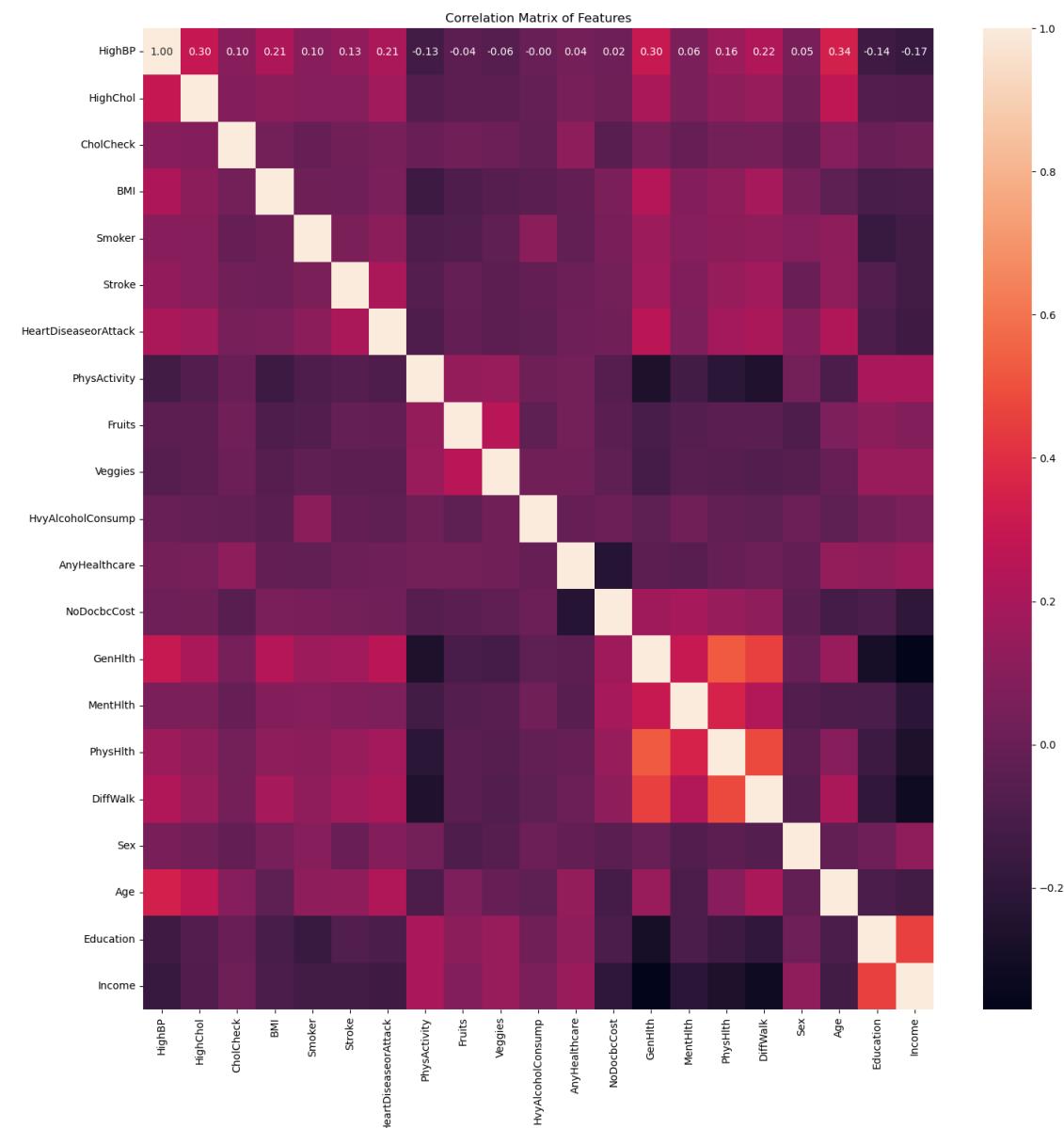
    # Target feature is diabetes
    ct = pd.crosstab(df[feature], df['Diabetes'])

    ct.plot(kind='bar', stacked=False, ax=plt.gca())
    plt.yscale('log')
    plt.title(f'Distribution of {feature} by Diabetes')
    plt.xlabel(feature)
    plt.ylabel('Count')
    plt.xticks(rotation=45)
    plt.legend(loc = 'lower right')
plt.tight_layout()
plt.show()
```



```
[23]: X = df.drop('Diabetes', axis=1)
y = df['Diabetes']
```

```
[24]: correlation_matrix = X.corr()
plt.figure(figsize=(17, 17))
sns.heatmap(correlation_matrix, annot=True, fmt=".2f")
plt.title('Correlation Matrix of Features')
plt.show()
```



```
[ ]:
```

```
[25]: # Calculate the absolute correlation matrix
correlation_matrix_ab = correlation_matrix.abs()

correlation_series = correlation_matrix_ab.unstack()

# Remove identical feature pairs
correlation_series = correlation_series[correlation_series < 1]

# Filter for correlations above 0.5
high_correlations = correlation_series[correlation_series > 0.5]

print("Correlations above 0.5:")
for (feature_pair, value) in high_correlations.items():
    print(f"{feature_pair}: {value}")
```

Correlations above 0.5:

```
('GenHlth', 'PhysHlth'): 0.5243636438493371
('PhysHlth', 'GenHlth'): 0.5243636438493371
```

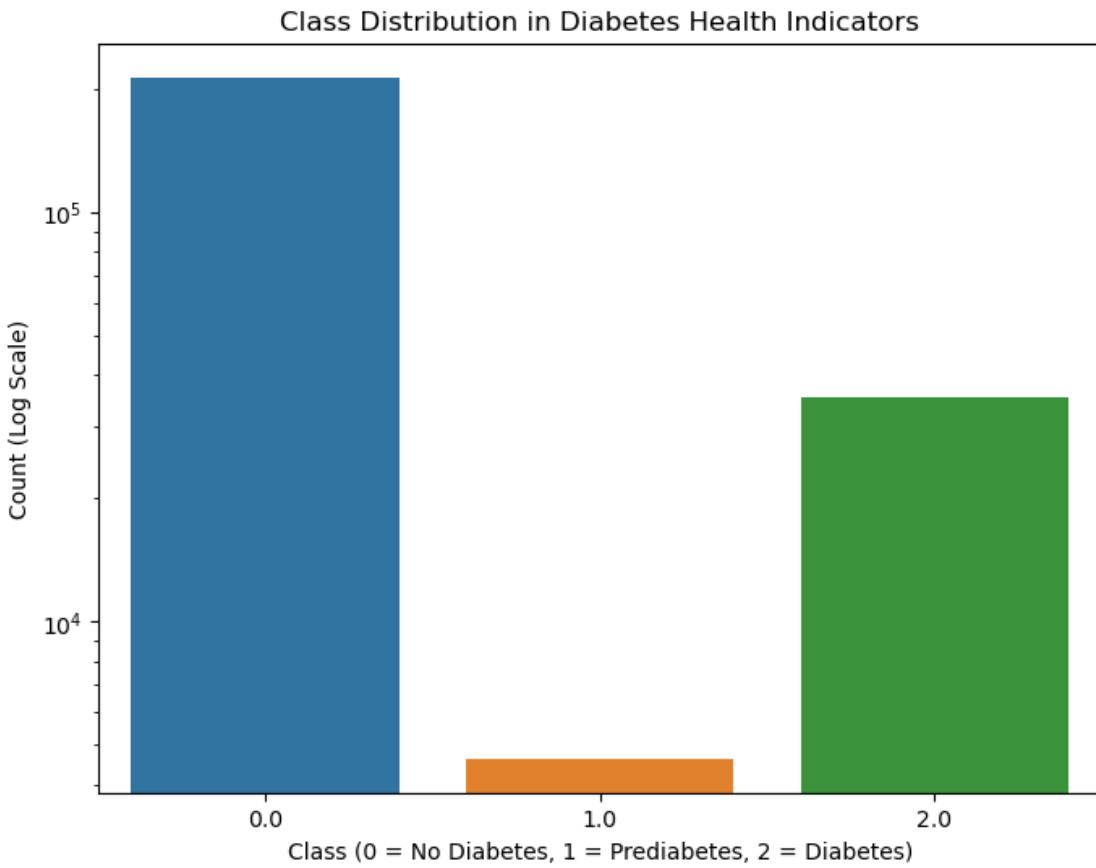
```
[26]: class_counts = df['Diabetes'].value_counts()
print(class_counts.sort_index())

# Format the proportions to 4 decimal places
proportions = class_counts.sort_index() / df['Diabetes'].shape[0]
print(proportions.apply(lambda x: f"{x:.4f}"))
```

```
Diabetes
0.0    213703
1.0     4631
2.0     35346
Name: count, dtype: int64
Diabetes
0.0    0.8424
1.0    0.0183
2.0    0.1393
Name: count, dtype: object
```

```
[27]: plt.figure(figsize=(8, 6))
sns.barplot(x=class_counts.index, y=class_counts.values)

plt.yscale('log') # Using log scale to handle the extreme imbalance
plt.xlabel('Class (0 = No Diabetes, 1 = Prediabetes, 2 = Diabetes)')
plt.ylabel('Count (Log Scale)')
plt.title('Class Distribution in Diabetes Health Indicators')
plt.show()
```



```
[28]: # Split the dataset into training (60%), validation (20%), and test (20%) sets.
X_dev, X_test, y_dev, y_test = train_test_split(X, y, test_size=0.2,
                                                stratify=y, random_state=42)

X_train, X_val, y_train, y_val = train_test_split(X_dev, y_dev, test_size=0.25,
                                                stratify=y_dev, ↴
                                                random_state=42)

print(f"Training data size: {len(y_train)}")
print(f"Validation data size: {len(y_val)}")
print(f"Test data size: {len(y_test)}")
```

```
Training data size: 152208
Validation data size: 50736
Test data size: 50736
```

```
[29]: scaler = StandardScaler()

X_dev[['BMI', 'MentHlth', 'PhysHlth']] = scaler.fit_transform(X_dev[['BMI', ↴
    'MentHlth', 'PhysHlth']])
```

```

X_test[['BMI', 'MentHlth', 'PhysHlth']] = scaler.transform(X_test[['BMI',
    ↪'MentHlth', 'PhysHlth']])

X_dev_scaled = pd.DataFrame(X_dev, columns=X.columns, index=X_dev.index)
X_test_scaled = pd.DataFrame(X_test, columns=X.columns, index=X_test.index)

X_dev_scaled.head()

```

[29]:

	HighBP	HighChol	CholCheck	BMI	Smoker	Stroke	\
185494	1.0	0.0	1.0	-0.512552	0.0	0.0	
217030	0.0	0.0	1.0	1.301115	1.0	0.0	
641	1.0	1.0	1.0	0.998837	0.0	0.0	
217863	0.0	0.0	1.0	-0.210274	0.0	0.0	
53677	0.0	0.0	1.0	-0.059135	1.0	0.0	

	HeartDiseaseorAttack	PhysActivity	Fruits	Veggies	...	\	
185494	0.0	1.0	1.0	1.0	1.0	...	
217030	0.0	1.0	1.0	1.0	1.0	...	
641	0.0	1.0	1.0	1.0	0.0	...	
217863	0.0	1.0	0.0	0.0	0.0	...	
53677	0.0	1.0	0.0	0.0	0.0	...	

	AnyHealthcare	NoDocbcCost	GenHlth	MentHlth	PhysHlth	DiffWalk	\
185494	1.0	0.0	2.0	-0.429290	-0.485961	0.0	
217030	1.0	0.0	1.0	-0.429290	-0.485961	0.0	
641	1.0	0.0	2.0	-0.429290	-0.485961	0.0	
217863	1.0	0.0	2.0	-0.429290	0.088138	0.0	
53677	1.0	1.0	3.0	-0.023967	-0.485961	0.0	

	Sex	Age	Education	Income
185494	1.0	10.0	4.0	4.0
217030	0.0	1.0	5.0	5.0
641	0.0	11.0	5.0	3.0
217863	1.0	3.0	4.0	6.0
53677	0.0	9.0	4.0	4.0

[5 rows x 21 columns]

[30]:

```

max_iter = 500

# Initialize the multinomial logistic regression model
mlg_bal = LogisticRegression(penalty='l2', C=1.0, multi_class='multinomial',
    solver='lbfgs', max_iter=max_iter,
    ↪class_weight='balanced', random_state=42, verbose=1)

scores = cross_val_score(mlg_bal, X_dev_scaled, y_dev, cv=10,
    ↪error_score="raise")

```

```

print("Cross-validation scores:", scores)
print("Mean cross-validation score:", np.mean(scores))

```

RUNNING THE L-BFGS-B CODE

\* \* \*

Machine precision = 2.220D-16

N = 66 M = 10

At X0 0 variables are exactly at the bounds

At iterate 0 f= 2.00660D+05 |proj g|= 5.86870D+04

[Parallel(n\_jobs=1)]: Using backend SequentialBackend with 1 concurrent workers.  
This problem is unconstrained.

At iterate 50 f= 1.74932D+05 |proj g|= 1.53723D+03

At iterate 100 f= 1.74014D+05 |proj g|= 2.21692D+03

At iterate 150 f= 1.73637D+05 |proj g|= 4.57941D+02

At iterate 200 f= 1.73611D+05 |proj g|= 6.32737D+02

At iterate 250 f= 1.73604D+05 |proj g|= 4.79169D+01

At iterate 300 f= 1.73603D+05 |proj g|= 2.79581D+01

\* \* \*

Tit = total number of iterations

Tnf = total number of function evaluations

Tnint = total number of segments explored during Cauchy searches

Skip = number of BFGS updates skipped

Nact = number of active bounds at final generalized Cauchy point

Projg = norm of the final projected gradient

F = final function value

\* \* \*

N	Tit	Tnf	Tnint	Skip	Nact	Projg	F
66	321	363	1	0	0	2.873D+01	1.736D+05
F =	173602.80727732569						

CONVERGENCE: REL\_REDUCTION\_OF\_F\_<=\_FACTR\*EPSMCH

RUNNING THE L-BFGS-B CODE

\* \* \*

Machine precision = 2.220D-16

N = 66 M = 10

At X0 0 variables are exactly at the bounds

At iterate 0 f= 2.00660D+05 |proj g|= 5.84726D+04

[Parallel(n\_jobs=1)]: Done 1 out of 1 | elapsed: 7.9s finished

[Parallel(n\_jobs=1)]: Using backend SequentialBackend with 1 concurrent workers.

This problem is unconstrained.

At iterate 50 f= 1.75035D+05 |proj g|= 1.50563D+04

At iterate 100 f= 1.73885D+05 |proj g|= 2.77268D+03

At iterate 150 f= 1.73601D+05 |proj g|= 6.54425D+02

At iterate 200 f= 1.73583D+05 |proj g|= 5.18794D+02

At iterate 250 f= 1.73576D+05 |proj g|= 8.99116D+01

At iterate 300 f= 1.73574D+05 |proj g|= 3.97526D+01

At iterate 350 f= 1.73574D+05 |proj g|= 7.23625D+01

[Parallel(n\_jobs=1)]: Done 1 out of 1 | elapsed: 10.1s finished

[Parallel(n\_jobs=1)]: Using backend SequentialBackend with 1 concurrent workers.

This problem is unconstrained.

\* \* \*

Tit = total number of iterations

Tnf = total number of function evaluations

Tnint = total number of segments explored during Cauchy searches

Skip = number of BFGS updates skipped

Nact = number of active bounds at final generalized Cauchy point

Projg = norm of the final projected gradient

F = final function value

\* \* \*

N	Tit	Tnf	Tnint	Skip	Nact	Projg	F
66	384	427	1	0	0	1.377D+01	1.736D+05
F =	173573.61964456397						

CONVERGENCE: REL\_REDUCTION\_OF\_F\_<=\_FACTR\*EPSMCH  
RUNNING THE L-BFGS-B CODE

\* \* \*

Machine precision = 2.220D-16

N = 66 M = 10

At X0 0 variables are exactly at the bounds

At iterate 0 f= 2.00660D+05 |proj g|= 5.86431D+04

At iterate 50 f= 1.74904D+05 |proj g|= 1.09138D+03

At iterate 100 f= 1.74061D+05 |proj g|= 3.80351D+03

At iterate 150 f= 1.73683D+05 |proj g|= 2.18132D+03

At iterate 200 f= 1.73629D+05 |proj g|= 5.24946D+02

At iterate 250 f= 1.73622D+05 |proj g|= 1.40576D+02

At iterate 300 f= 1.73618D+05 |proj g|= 7.67626D+01

At iterate 350 f= 1.73618D+05 |proj g|= 3.42160D+01

At iterate 400 f= 1.73617D+05 |proj g|= 1.93569D+01

[Parallel(n\_jobs=1)]: Done 1 out of 1 | elapsed: 11.6s finished

[Parallel(n\_jobs=1)]: Using backend SequentialBackend with 1 concurrent workers.  
This problem is unconstrained.

\* \* \*

Tit = total number of iterations

Tnf = total number of function evaluations

Tnint = total number of segments explored during Cauchy searches

Skip = number of BFGS updates skipped

Nact = number of active bounds at final generalized Cauchy point

Projg = norm of the final projected gradient

F = final function value

\* \* \*

N	Tit	Tnf	Tnint	Skip	Nact	Projg	F
66	449	505	1	0	0	3.601D+01	1.736D+05
F =	173617.11807783050						

CONVERGENCE: REL\_REDUCTION\_OF\_F\_<=\_FACTR\*EPSMCH  
RUNNING THE L-BFGS-B CODE

\* \* \*

Machine precision = 2.220D-16

N = 66 M = 10

At X0 0 variables are exactly at the bounds

At iterate 0 f= 2.00660D+05 |proj g|= 5.86808D+04

At iterate 50 f= 1.75132D+05 |proj g|= 2.13400D+03

At iterate 100 f= 1.74121D+05 |proj g|= 2.61842D+03

At iterate 150 f= 1.73780D+05 |proj g|= 1.09611D+03

At iterate 200 f= 1.73755D+05 |proj g|= 1.63666D+02

At iterate 250 f= 1.73749D+05 |proj g|= 1.37444D+02

At iterate 300 f= 1.73747D+05 |proj g|= 7.28076D+01

[Parallel(n\_jobs=1)]: Done 1 out of 1 | elapsed: 8.9s finished

[Parallel(n\_jobs=1)]: Using backend SequentialBackend with 1 concurrent workers.  
This problem is unconstrained.

\* \* \*

Tit = total number of iterations

Tnf = total number of function evaluations

Tnint = total number of segments explored during Cauchy searches

Skip = number of BFGS updates skipped

Nact = number of active bounds at final generalized Cauchy point

Projg = norm of the final projected gradient

F = final function value

\* \* \*

N	Tit	Tnf	Tnint	Skip	Nact	Projg	F
66	334	377	1	0	0	6.110D+01	1.737D+05
F =	173746.80646513004						

CONVERGENCE: REL\_REDUCTION\_OF\_F\_<=\_FACTR\*EPSMCH  
RUNNING THE L-BFGS-B CODE

\* \* \*

```

Machine precision = 2.220D-16
N = 66 M = 10

At X0 0 variables are exactly at the bounds

At iterate 0 f= 2.00662D+05 |proj g|= 5.81988D+04

At iterate 50 f= 1.75092D+05 |proj g|= 8.22067D+03

At iterate 100 f= 1.74194D+05 |proj g|= 1.61507D+03

At iterate 150 f= 1.73812D+05 |proj g|= 8.58165D+02

At iterate 200 f= 1.73773D+05 |proj g|= 1.46200D+02

At iterate 250 f= 1.73765D+05 |proj g|= 4.53119D+02

At iterate 300 f= 1.73763D+05 |proj g|= 2.77571D+01

At iterate 350 f= 1.73763D+05 |proj g|= 4.43712D+01

[Parallel(n_jobs=1)]: Done 1 out of 1 | elapsed: 8.4s finished
[Parallel(n_jobs=1)]: Using backend SequentialBackend with 1 concurrent workers.
This problem is unconstrained.

```

\* \* \*

Tit = total number of iterations  
 Tnf = total number of function evaluations  
 Tnint = total number of segments explored during Cauchy searches  
 Skip = number of BFGS updates skipped  
 Nact = number of active bounds at final generalized Cauchy point  
 Projg = norm of the final projected gradient  
 F = final function value

\* \* \*

N	Tit	Tnf	Tnint	Skip	Nact	Projg	F
66	380	425	1	0	0	6.238D+01	1.738D+05
F =	173762.77582167109						

CONVERGENCE: REL\_REDUCTION\_OF\_F\_<=\_FACTR\*EPSMCH  
 RUNNING THE L-BFGS-B CODE

\* \* \*

Machine precision = 2.220D-16

```

N =           66      M =           10

At X0          0 variables are exactly at the bounds

At iterate    0      f=  2.00662D+05      |proj g|=  5.86282D+04
At iterate   50      f=  1.75148D+05      |proj g|=  6.81448D+03
At iterate  100      f=  1.74141D+05      |proj g|=  5.70075D+03
At iterate  150      f=  1.73818D+05      |proj g|=  6.16516D+02
At iterate  200      f=  1.73779D+05      |proj g|=  4.11201D+02
At iterate  250      f=  1.73773D+05      |proj g|=  1.76445D+02
At iterate  300      f=  1.73769D+05      |proj g|=  3.75470D+01

[Parallel(n_jobs=1)]: Done   1 out of   1 | elapsed:  10.1s finished
[Parallel(n_jobs=1)]: Using backend SequentialBackend with 1 concurrent workers.
This problem is unconstrained.

```

\* \* \*

Tit = total number of iterations  
 Tnf = total number of function evaluations  
 Tnint = total number of segments explored during Cauchy searches  
 Skip = number of BFGS updates skipped  
 Nact = number of active bounds at final generalized Cauchy point  
 Projg = norm of the final projected gradient  
 F = final function value

\* \* \*

N	Tit	Tnf	Tnint	Skip	Nact	Projg	F
66	347	386	1	0	0	3.120D+01	1.738D+05
F =	173769.20891762120						

CONVERGENCE: REL\_REDUCTION\_OF\_F\_<=\_FACTR\*EPSMCH  
 RUNNING THE L-BFGS-B CODE

\* \* \*

Machine precision = 2.220D-16  
 N = 66 M = 10

At X0 0 variables are exactly at the bounds

```

At iterate    0      f=  2.00662D+05      |proj g|=  5.80841D+04
At iterate   50      f=  1.75131D+05      |proj g|=  1.94212D+03
At iterate  100      f=  1.74091D+05      |proj g|=  2.13697D+03
At iterate  150      f=  1.73825D+05      |proj g|=  8.36864D+02
At iterate  200      f=  1.73800D+05      |proj g|=  2.99600D+02
At iterate  250      f=  1.73796D+05      |proj g|=  1.60491D+02
At iterate  300      f=  1.73792D+05      |proj g|=  3.17894D+01
At iterate  350      f=  1.73792D+05      |proj g|=  2.05167D+01
[Parallel(n_jobs=1)]: Done   1 out of   1 | elapsed:   9.5s finished
[Parallel(n_jobs=1)]: Using backend SequentialBackend with 1 concurrent workers.
This problem is unconstrained.

```

\* \* \*

Tit = total number of iterations  
 Tnf = total number of function evaluations  
 Tnint = total number of segments explored during Cauchy searches  
 Skip = number of BFGS updates skipped  
 Nact = number of active bounds at final generalized Cauchy point  
 Projg = norm of the final projected gradient  
 F = final function value

\* \* \*

N	Tit	Tnf	Tnint	Skip	Nact	Projg	F
66	365	409	1	0	0	8.526D+01	1.738D+05
F =	173792.08549710625						

CONVERGENCE: REL\_REDUCTION\_OF\_F\_<=\_FACTR\*EPSMCH  
 RUNNING THE L-BFGS-B CODE

\* \* \*

Machine precision = 2.220D-16  
 N = 66 M = 10

At X0 0 variables are exactly at the bounds

At iterate 0 f= 2.00662D+05 |proj g|= 5.89084D+04

```

At iterate  50      f=  1.74922D+05    |proj g|=  1.60810D+03
At iterate 100      f=  1.73906D+05    |proj g|=  5.66362D+03
At iterate 150      f=  1.73620D+05    |proj g|=  7.97610D+02
At iterate 200      f=  1.73582D+05    |proj g|=  1.88669D+02
At iterate 250      f=  1.73574D+05    |proj g|=  2.02223D+02
At iterate 300      f=  1.73571D+05    |proj g|=  7.18521D+01
At iterate 350      f=  1.73571D+05    |proj g|=  6.13361D+01
[Parallel(n_jobs=1)]: Done   1 out of   1 | elapsed:    7.7s finished
[Parallel(n_jobs=1)]: Using backend SequentialBackend with 1 concurrent workers.
This problem is unconstrained.

```

\* \* \*

Tit = total number of iterations  
 Tnf = total number of function evaluations  
 Tnint = total number of segments explored during Cauchy searches  
 Skip = number of BFGS updates skipped  
 Nact = number of active bounds at final generalized Cauchy point  
 Projg = norm of the final projected gradient  
 F = final function value

\* \* \*

N	Tit	Tnf	Tnint	Skip	Nact	Projg	F
66	366	413	1	0	0	3.590D+01	1.736D+05
F =	173570.72952053862						

CONVERGENCE: REL\_REDUCTION\_OF\_F\_<=\_FACTR\*EPSMCH  
 RUNNING THE L-BFGS-B CODE

\* \* \*

Machine precision = 2.220D-16  
 N = 66 M = 10

At X0 0 variables are exactly at the bounds

```

At iterate  0      f=  2.00662D+05    |proj g|=  5.84619D+04
At iterate  50     f=  1.75117D+05    |proj g|=  5.83305D+03

```

```

At iterate 100      f= 1.74200D+05      |proj g|= 3.18690D+03
At iterate 150      f= 1.73709D+05      |proj g|= 5.67193D+02
At iterate 200      f= 1.73666D+05      |proj g|= 1.50840D+02
At iterate 250      f= 1.73656D+05      |proj g|= 1.36046D+02
At iterate 300      f= 1.73652D+05      |proj g|= 3.31677D+02
[Parallel(n_jobs=1)]: Done   1 out of   1 | elapsed:    6.9s finished
[Parallel(n_jobs=1)]: Using backend SequentialBackend with 1 concurrent workers.
This problem is unconstrained.

```

\* \* \*

Tit = total number of iterations  
 Tnf = total number of function evaluations  
 Tnint = total number of segments explored during Cauchy searches  
 Skip = number of BFGS updates skipped  
 Nact = number of active bounds at final generalized Cauchy point  
 Projg = norm of the final projected gradient  
 F = final function value

\* \* \*

N	Tit	Tnf	Tnint	Skip	Nact	Projg	F
66	342	386	1	0	0	6.480D+01	1.737D+05
F =	173651.45207412445						

CONVERGENCE: REL\_REDUCTION\_OF\_F\_<=\_FACTR\*EPSMCH  
 RUNNING THE L-BFGS-B CODE

\* \* \*

Machine precision = 2.220D-16  
 N = 66 M = 10

At X0 0 variables are exactly at the bounds

```

At iterate 0      f= 2.00662D+05      |proj g|= 5.84398D+04
At iterate 50     f= 1.75279D+05      |proj g|= 5.09087D+03
At iterate 100    f= 1.74149D+05      |proj g|= 3.09698D+03
At iterate 150    f= 1.73742D+05      |proj g|= 6.90705D+02

```

```

At iterate 200      f= 1.73715D+05      |proj g|= 3.53352D+02
At iterate 250      f= 1.73707D+05      |proj g|= 1.46243D+02
At iterate 300      f= 1.73705D+05      |proj g|= 5.85998D+01
At iterate 350      f= 1.73705D+05      |proj g|= 2.53179D+01

* * *

Tit = total number of iterations
Tnf = total number of function evaluations
Tnint = total number of segments explored during Cauchy searches
Skip = number of BFGS updates skipped
Nact = number of active bounds at final generalized Cauchy point
Projg = norm of the final projected gradient
F = final function value

* * *

      N   Tit     Tnf   Tnint   Skip   Nact     Projg         F
      66   355     398       1       0       0   6.722D+00   1.737D+05
      F = 173704.55217073768

CONVERGENCE: REL_REDUCTION_OF_F_<=_FACTR*EPSMCH
Cross-validation scores: [0.64306479 0.64405026 0.64616901 0.64217788 0.64526461
0.64511678
0.64797477 0.64097763 0.6466936 0.64684143]
Mean cross-validation score: 0.6448330764662636
[Parallel(n_jobs=1)]: Done    1 out of    1 | elapsed:    8.8s finished

```

```
[31]: # Define the parameter grid for tuning
param_grid = {
    'C': [0.01, 0.1, 1, 10, 100]
}

model = LogisticRegression(multi_class='multinomial', solver='lbfgs',
                           max_iter=max_iter, class_weight='balanced', ↴
                           random_state=42, verbose=1)

grid_search = GridSearchCV(estimator=model, param_grid=param_grid, cv=10, ↴
                           scoring='accuracy', n_jobs=-1)

grid_search.fit(X_dev_scaled, y_dev)
print("Best Parameters:", grid_search.best_params_)
print("Best Cross-Validation Score:", grid_search.best_score_)
```

```
[Parallel(n_jobs=1)]: Using backend SequentialBackend with 1 concurrent workers.  
This problem is unconstrained.  
This problem is unconstrained.
```

RUNNING THE L-BFGS-B CODE

\* \* \*

```
Machine precision = 2.220D-16  
N = 66 M = 10
```

At X0 0 variables are exactly at the bounds

```
At iterate 0 f= 2.00662D+05 |proj g|= 5.81988D+04  
RUNNING THE L-BFGS-B CODE
```

\* \* \*

```
Machine precision = 2.220D-16  
N = 66 M = 10
```

At X0 0 variables are exactly at the bounds

```
At iterate 0 f= 2.00660D+05 |proj g|= 5.86431D+04  
RUNNING THE L-BFGS-B CODE
```

\* \* \*

```
Machine precision = 2.220D-16  
N = 66 M = 10
```

At X0 0 variables are exactly at the bounds

```
At iterate 0 f= 2.00660D+05 |proj g|= 5.84726D+04  
RUNNING THE L-BFGS-B CODE
```

\* \* \*

Machine precision = 2.220D-16

N = 66 M = 10

At X0 0 variables are exactly at the bounds

At iterate 0 f= 2.00662D+05 |proj g|= 5.80841D+04

RUNNING THE L-BFGS-B CODE

\* \* \*

Machine precision = 2.220D-16

N = 66 M = 10

At X0 0 variables are exactly at the bounds

At iterate 0 f= 2.00662D+05 |proj g|= 5.86282D+04

RUNNING THE L-BFGS-B CODE

\* \* \*

Machine precision = 2.220D-16

N = 66 M = 10

At X0 0 variables are exactly at the bounds

At iterate 0 f= 2.00660D+05 |proj g|= 5.86808D+04

RUNNING THE L-BFGS-B CODE

\* \* \*

Machine precision = 2.220D-16

N = 66 M = 10

At X0 0 variables are exactly at the bounds

At iterate 0 f= 2.00660D+05 |proj g|= 5.86870D+04

RUNNING THE L-BFGS-B CODE

\* \* \*

Machine precision = 2.220D-16

N = 66 M = 10

At X0 0 variables are exactly at the bounds

At iterate	0	f= 2.00662D+05	proj g = 5.89084D+04
At iterate	50	f= 1.74981D+05	proj g = 3.36011D+03
At iterate	50	f= 1.75153D+05	proj g = 1.10319D+04
At iterate	50	f= 1.75223D+05	proj g = 1.91473D+03
At iterate	50	f= 1.75219D+05	proj g = 3.17152D+03
At iterate	50	f= 1.75165D+05	proj g = 1.92111D+03
At iterate	50	f= 1.74954D+05	proj g = 2.95642D+03
At iterate	50	f= 1.75141D+05	proj g = 5.87774D+03
At iterate	50	f= 1.75206D+05	proj g = 3.30814D+03
At iterate	100	f= 1.74042D+05	proj g = 5.24727D+03
At iterate	100	f= 1.73971D+05	proj g = 4.43195D+03
At iterate	100	f= 1.74158D+05	proj g = 1.77467D+03
At iterate	100	f= 1.74168D+05	proj g = 2.83915D+03
At iterate	100	f= 1.74081D+05	proj g = 1.79222D+03
At iterate	100	f= 1.73965D+05	proj g = 4.37086D+03
At iterate	100	f= 1.74312D+05	proj g = 4.59623D+03
At iterate	100	f= 1.74162D+05	proj g = 3.36178D+03
At iterate	150	f= 1.73740D+05	proj g = 3.50915D+02
At iterate	150	f= 1.73727D+05	proj g = 7.79112D+02
At iterate	150	f= 1.73713D+05	proj g = 2.74476D+02
At iterate	150	f= 1.73908D+05	proj g = 5.68632D+02
At iterate	150	f= 1.73878D+05	proj g = 9.73025D+02
At iterate	150	f= 1.73741D+05	proj g = 1.27792D+02
At iterate	150	f= 1.73918D+05	proj g = 8.49709D+02

At iterate	150	$f = 1.73925D+05$	$ \text{proj } g  = 6.43106D+02$
At iterate	200	$f = 1.73717D+05$	$ \text{proj } g  = 2.09030D+02$
At iterate	200	$f = 1.73863D+05$	$ \text{proj } g  = 2.69674D+02$
At iterate	200	$f = 1.73691D+05$	$ \text{proj } g  = 1.91245D+02$
At iterate	200	$f = 1.73729D+05$	$ \text{proj } g  = 1.36611D+02$
At iterate	200	$f = 1.73882D+05$	$ \text{proj } g  = 7.61131D+01$
At iterate	200	$f = 1.73692D+05$	$ \text{proj } g  = 1.46629D+02$
At iterate	200	$f = 1.73879D+05$	$ \text{proj } g  = 2.31751D+02$
At iterate	200	$f = 1.73907D+05$	$ \text{proj } g  = 3.35244D+02$
At iterate	250	$f = 1.73713D+05$	$ \text{proj } g  = 1.89975D+02$
At iterate	250	$f = 1.73878D+05$	$ \text{proj } g  = 4.98384D+01$
At iterate	250	$f = 1.73687D+05$	$ \text{proj } g  = 2.31485D+02$
At iterate	250	$f = 1.73725D+05$	$ \text{proj } g  = 1.64362D+02$
At iterate	250	$f = 1.73859D+05$	$ \text{proj } g  = 5.74621D+01$
At iterate	250	$f = 1.73688D+05$	$ \text{proj } g  = 2.30917D+02$
At iterate	250	$f = 1.73873D+05$	$ \text{proj } g  = 3.75410D+02$
At iterate	250	$f = 1.73903D+05$	$ \text{proj } g  = 3.74283D+01$
At iterate	300	$f = 1.73712D+05$	$ \text{proj } g  = 5.29922D+01$
At iterate	300	$f = 1.73877D+05$	$ \text{proj } g  = 5.32215D+01$
At iterate	300	$f = 1.73685D+05$	$ \text{proj } g  = 1.82216D+01$
At iterate	300	$f = 1.73858D+05$	$ \text{proj } g  = 7.28364D+01$
At iterate	300	$f = 1.73724D+05$	$ \text{proj } g  = 3.26201D+01$
At iterate	300	$f = 1.73687D+05$	$ \text{proj } g  = 3.52053D+01$
At iterate	300	$f = 1.73870D+05$	$ \text{proj } g  = 5.75761D+01$

```
At iterate 300      f= 1.73902D+05      |proj g|= 2.19771D+01
```

```
* * *
```

```
Tit = total number of iterations  
Tnf = total number of function evaluations  
Tnint = total number of segments explored during Cauchy searches  
Skip = number of BFGS updates skipped  
Nact = number of active bounds at final generalized Cauchy point  
Projg = norm of the final projected gradient  
F = final function value
```

```
* * *
```

N	Tit	Tnf	Tnint	Skip	Nact	Projg	F
66	311	347	1	0	0	2.479D+01	1.737D+05
F =	173724.35409613300						

```
CONVERGENCE: REL_REDUCTION_OF_F_<=_FACTR*EPSMCH
```

```
* * *
```

```
Tit = total number of iterations  
Tnf = total number of function evaluations  
Tnint = total number of segments explored during Cauchy searches  
Skip = number of BFGS updates skipped  
Nact = number of active bounds at final generalized Cauchy point  
Projg = norm of the final projected gradient  
F = final function value
```

```
* * *
```

N	Tit	Tnf	Tnint	Skip	Nact	Projg	F
66	326	359	1	0	0	5.320D+01	1.737D+05
F =	173712.13993520089						

```
CONVERGENCE: REL_REDUCTION_OF_F_<=_FACTR*EPSMCH
```

```
* * *
```

```
Tit = total number of iterations  
Tnf = total number of function evaluations  
Tnint = total number of segments explored during Cauchy searches  
Skip = number of BFGS updates skipped  
Nact = number of active bounds at final generalized Cauchy point  
Projg = norm of the final projected gradient  
F = final function value
```

\* \* \*

N	Tit	Tnf	Tnint	Skip	Nact	Projg	F
66	321	357	1	0	0	1.236D+01	1.739D+05
F =	173876.60605605631						

CONVERGENCE: REL\_REDUCTION\_OF\_F\_<=\_FACTR\*EPSMCH

\* \* \*

Tit = total number of iterations  
Tnf = total number of function evaluations  
Tnint = total number of segments explored during Cauchy searches  
Skip = number of BFGS updates skipped  
Nact = number of active bounds at final generalized Cauchy point  
Projg = norm of the final projected gradient  
F = final function value

\* \* \*

N	Tit	Tnf	Tnint	Skip	Nact	Projg	F
66	317	355	1	0	0	1.123D+01	1.737D+05
F =	173685.27532996051						

CONVERGENCE: REL\_REDUCTION\_OF\_F\_<=\_FACTR\*EPSMCH

RUNNING THE L-BFGS-B CODE

\* \* \*

Machine precision = 2.220D-16

N = 66 M = 10

At X0 0 variables are exactly at the bounds

At iterate 0 f= 2.00662D+05 |proj g|= 5.84398D+04

[Parallel(n\_jobs=1)]: Done 1 out of 1 | elapsed: 6.3s finished  
[Parallel(n\_jobs=1)]: Done 1 out of 1 | elapsed: 6.2s finished  
[Parallel(n\_jobs=1)]: Done 1 out of 1 | elapsed: 6.3s finished  
[Parallel(n\_jobs=1)]: Done 1 out of 1 | elapsed: 6.3s finished  
[Parallel(n\_jobs=1)]: Using backend SequentialBackend with 1 concurrent workers.  
[Parallel(n\_jobs=1)]: Using backend SequentialBackend with 1 concurrent workers.  
This problem is unconstrained.  
[Parallel(n\_jobs=1)]: Using backend SequentialBackend with 1 concurrent workers.  
This problem is unconstrained.

RUNNING THE L-BFGS-B CODE

\* \* \*

```

Machine precision = 2.220D-16
N =           66      M =           10

At X0          0 variables are exactly at the bounds

At iterate    0      f=  2.00662D+05      |proj g|=  5.84619D+04
RUNNING THE L-BFGS-B CODE

```

\* \* \*

```

Machine precision = 2.220D-16
N =           66      M =           10

At X0          0 variables are exactly at the bounds

At iterate    0      f=  2.00660D+05      |proj g|=  5.86870D+04
RUNNING THE L-BFGS-B CODE

```

\* \* \*

```

Machine precision = 2.220D-16
N =           66      M =           10

At X0          0 variables are exactly at the bounds

At iterate    0      f=  2.00660D+05      |proj g|=  5.84726D+04

```

\* \* \*

```

Tit   = total number of iterations
Tnf   = total number of function evaluations
Tnint = total number of segments explored during Cauchy searches
Skip  = number of BFGS updates skipped
Nact  = number of active bounds at final generalized Cauchy point
Projg = norm of the final projected gradient
F     = final function value

```

\* \* \*

N	Tit	Tnf	Tnint	Skip	Nact	Projg	F
66	326	366	1	0	0	1.032D+01	1.739D+05
F =	173858.10686032497						

CONVERGENCE: REL\_REDUCTION\_OF\_F\_<=\_FACTR\*EPSMCH

\* \* \*

Tit = total number of iterations  
 Tnf = total number of function evaluations  
 Tnint = total number of segments explored during Cauchy searches  
 Skip = number of BFGS updates skipped  
 Nact = number of active bounds at final generalized Cauchy point  
 Projg = norm of the final projected gradient  
 F = final function value

\* \* \*

N	Tit	Tnf	Tnint	Skip	Nact	Projg	F
66	328	368	1	0	0	5.281D+01	1.737D+05
F =	173686.92763859205						

CONVERGENCE: REL\_REDUCTION\_OF\_F\_<=\_FACTR\*EPSMCH

[Parallel(n\_jobs=1)]: Using backend SequentialBackend with 1 concurrent workers.  
 This problem is unconstrained.  
 This problem is unconstrained.  
 [Parallel(n\_jobs=1)]: Done 1 out of 1 | elapsed: 6.6s finished  
 [Parallel(n\_jobs=1)]: Done 1 out of 1 | elapsed: 6.6s finished  
 [Parallel(n\_jobs=1)]: Using backend SequentialBackend with 1 concurrent workers.  
 This problem is unconstrained.  
 [Parallel(n\_jobs=1)]: Using backend SequentialBackend with 1 concurrent workers.  
 This problem is unconstrained.  
 [Parallel(n\_jobs=1)]: Done 1 out of 1 | elapsed: 6.8s finished

RUNNING THE L-BFGS-B CODE

\* \* \*

Machine precision = 2.220D-16  
 N = 66 M = 10

At X0 0 variables are exactly at the bounds

At iterate 0 f= 2.00660D+05 |proj g|= 5.86431D+04  
 RUNNING THE L-BFGS-B CODE

\* \* \*

Machine precision = 2.220D-16  
 N = 66 M = 10

At X0 0 variables are exactly at the bounds

At iterate 0 f= 2.00660D+05 |proj g|= 5.86808D+04

\* \* \*

Tit = total number of iterations  
 Tnf = total number of function evaluations  
 Tnint = total number of segments explored during Cauchy searches  
 Skip = number of BFGS updates skipped  
 Nact = number of active bounds at final generalized Cauchy point  
 Projg = norm of the final projected gradient  
 F = final function value

\* \* \*

N	Tit	Tnf	Tnint	Skip	Nact	Projg	F
66	336	373	1	0	0	8.070D+00	1.739D+05
F = 173869.15938684126							

CONVERGENCE: REL\_REDUCTION\_OF\_F\_<=\_FACTR\*EPSMCH

[Parallel(n\_jobs=1)]: Using backend SequentialBackend with 1 concurrent workers.  
 This problem is unconstrained.

RUNNING THE L-BFGS-B CODE

\* \* \*

Machine precision = 2.220D-16

N = 66 M = 10

At X0 0 variables are exactly at the bounds

At iterate 0 f= 2.00662D+05 |proj g|= 5.81988D+04

At iterate 350 f= 1.73902D+05 |proj g|= 1.12220D+02

At iterate 50 f= 1.75250D+05 |proj g|= 8.94516D+03

At iterate 50 f= 1.75131D+05 |proj g|= 3.46380D+03

At iterate 50 f= 1.75053D+05 |proj g|= 1.46241D+04

At iterate 50 f= 1.74990D+05 |proj g|= 4.33011D+03

At iterate 50 f= 1.74953D+05 |proj g|= 1.70538D+03

At iterate 50 f= 1.75084D+05 |proj g|= 2.58607D+03

At iterate 50 f= 1.75213D+05 |proj g|= 9.31805D+03

At iterate 400 f= 1.73902D+05 |proj g|= 2.75788D+01

\* \* \*

Tit = total number of iterations  
Tnf = total number of function evaluations  
Tnint = total number of segments explored during Cauchy searches  
Skip = number of BFGS updates skipped  
Nact = number of active bounds at final generalized Cauchy point  
Projg = norm of the final projected gradient  
F = final function value

\* \* \*

N	Tit	Tnf	Tnint	Skip	Nact	Projg	F
66	402	451	1	0	0	1.292D+01	1.739D+05
F =	173901.95964924296						

CONVERGENCE: REL\_REDUCTION\_OF\_F\_<=\_FACTR\*EPSMCH

[Parallel(n\_jobs=1)]: Done 1 out of 1 | elapsed: 8.1s finished  
[Parallel(n\_jobs=1)]: Using backend SequentialBackend with 1 concurrent workers.  
This problem is unconstrained.

RUNNING THE L-BFGS-B CODE

\* \* \*

Machine precision = 2.220D-16

N = 66 M = 10

At X0 0 variables are exactly at the bounds

At iterate 0 f= 2.00662D+05	proj g = 5.86282D+04
At iterate 100 f= 1.73862D+05	proj g = 3.46902D+03
At iterate 100 f= 1.73980D+05	proj g = 1.95194D+03
At iterate 100 f= 1.74009D+05	proj g = 1.33068D+03
At iterate 100 f= 1.74103D+05	proj g = 3.99661D+03
At iterate 100 f= 1.74057D+05	proj g = 2.40185D+03
At iterate 100 f= 1.73990D+05	proj g = 3.14100D+03
At iterate 100 f= 1.74184D+05	proj g = 1.70317D+03
At iterate 50 f= 1.75162D+05	proj g = 3.26792D+03

At iterate	150	f= 1.73779D+05	proj g = 4.85881D+02
At iterate	150	f= 1.73638D+05	proj g = 5.69340D+02
At iterate	150	f= 1.73627D+05	proj g = 3.20184D+03
At iterate	150	f= 1.73834D+05	proj g = 3.19769D+02
At iterate	150	f= 1.73785D+05	proj g = 1.13503D+03
At iterate	150	f= 1.73669D+05	proj g = 1.69474D+03
At iterate	150	f= 1.73815D+05	proj g = 4.89341D+02
At iterate	100	f= 1.74103D+05	proj g = 6.91114D+02
At iterate	200	f= 1.73767D+05	proj g = 1.86275D+02
At iterate	200	f= 1.73816D+05	proj g = 2.21385D+02
At iterate	200	f= 1.73621D+05	proj g = 4.48546D+02
At iterate	200	f= 1.73592D+05	proj g = 8.65688D+01
At iterate	200	f= 1.73764D+05	proj g = 1.15449D+02
At iterate	200	f= 1.73636D+05	proj g = 3.30310D+02
At iterate	200	f= 1.73783D+05	proj g = 7.33707D+02
At iterate	150	f= 1.73808D+05	proj g = 1.18168D+03
At iterate	250	f= 1.73764D+05	proj g = 1.03611D+02
At iterate	250	f= 1.73813D+05	proj g = 1.74161D+02
At iterate	250	f= 1.73615D+05	proj g = 5.99166D+01
At iterate	250	f= 1.73586D+05	proj g = 2.63816D+02
At iterate	250	f= 1.73630D+05	proj g = 2.76740D+02
At iterate	250	f= 1.73759D+05	proj g = 1.37812D+02
At iterate	250	f= 1.73775D+05	proj g = 1.71608D+02
At iterate	200	f= 1.73787D+05	proj g = 1.05150D+02

```

At iterate 300      f=  1.73763D+05    |proj g|=  3.01532D+01
At iterate 300      f=  1.73614D+05    |proj g|=  4.84140D+01
At iterate 300      f=  1.73812D+05    |proj g|=  3.01641D+01
At iterate 300      f=  1.73585D+05    |proj g|=  4.88613D+01
At iterate 300      f=  1.73628D+05    |proj g|=  7.59104D+01
At iterate 300      f=  1.73758D+05    |proj g|=  2.64647D+01

```

\* \* \*

Tit = total number of iterations  
 Tnf = total number of function evaluations  
 Tnint = total number of segments explored during Cauchy searches  
 Skip = number of BFGS updates skipped  
 Nact = number of active bounds at final generalized Cauchy point  
 Projg = norm of the final projected gradient  
 F = final function value

\* \* \*

N	Tit	Tnf	Tnint	Skip	Nact	Projg	F
66	319	359	1	0	0	1.382D+01	1.738D+05
F =	173763.01228476557						

CONVERGENCE: REL\_REDUCTION\_OF\_F\_<=\_FACTR\*EPSMCH

[Parallel(n\_jobs=1)]: Done 1 out of 1 | elapsed: 6.2s finished  
 [Parallel(n\_jobs=1)]: Using backend SequentialBackend with 1 concurrent workers.  
 This problem is unconstrained.

RUNNING THE L-BFGS-B CODE

\* \* \*

Machine precision = 2.220D-16  
 N = 66 M = 10

At X0 0 variables are exactly at the bounds

```

At iterate 0      f=  2.00662D+05    |proj g|=  5.80841D+04
At iterate 300     f=  1.73773D+05    |proj g|=  7.00312D+01

```

\* \* \*

Tit = total number of iterations  
 Tnf = total number of function evaluations  
 Tnint = total number of segments explored during Cauchy searches  
 Skip = number of BFGS updates skipped  
 Nact = number of active bounds at final generalized Cauchy point  
 Projg = norm of the final projected gradient  
 F = final function value

\* \* \*

N	Tit	Tnf	Tnint	Skip	Nact	Projg	F
66	318	357	1	0	0	3.892D+01	1.738D+05
F =	173757.70609389510						

CONVERGENCE: REL\_REDUCTION\_OF\_F\_<=\_FACTR\*EPSMCH

[Parallel(n\_jobs=1)]: Done 1 out of 1 | elapsed: 6.1s finished  
 [Parallel(n\_jobs=1)]: Done 1 out of 1 | elapsed: 6.5s finished  
 [Parallel(n\_jobs=1)]: Using backend SequentialBackend with 1 concurrent workers.  
 [Parallel(n\_jobs=1)]: Using backend SequentialBackend with 1 concurrent workers.  
 This problem is unconstrained.  
 This problem is unconstrained.

\* \* \*

Tit = total number of iterations  
 Tnf = total number of function evaluations  
 Tnint = total number of segments explored during Cauchy searches  
 Skip = number of BFGS updates skipped  
 Nact = number of active bounds at final generalized Cauchy point  
 Projg = norm of the final projected gradient  
 F = final function value

\* \* \*

N	Tit	Tnf	Tnint	Skip	Nact	Projg	F
66	323	366	1	0	0	4.592D+00	1.738D+05
F =	173812.05971741781						

CONVERGENCE: REL\_REDUCTION\_OF\_F\_<=\_FACTR\*EPSMCH

RUNNING THE L-BFGS-B CODE

\* \* \*

Machine precision = 2.220D-16

N = 66 M = 10

At X0 0 variables are exactly at the bounds

```
At iterate    0      f=  2.00662D+05      |proj g|=  5.89084D+04
RUNNING THE L-BFGS-B CODE
```

```
* * *
```

```
Machine precision = 2.220D-16
```

```
N =          66      M =          10
```

```
At X0          0 variables are exactly at the bounds
```

```
At iterate    0      f=  2.00662D+05      |proj g|=  5.84619D+04
```

```
At iterate   250     f=  1.73781D+05      |proj g|=  8.21010D+01
```

```
* * *
```

```
Tit = total number of iterations
```

```
Tnf = total number of function evaluations
```

```
Tnint = total number of segments explored during Cauchy searches
```

```
Skip = number of BFGS updates skipped
```

```
Nact = number of active bounds at final generalized Cauchy point
```

```
Projg = norm of the final projected gradient
```

```
F = final function value
```

```
* * *
```

N	Tit	Tnf	Tnint	Skip	Nact	Projg	F
66	339	383	1	0	0	1.270D+01	1.736D+05
F =	173584.59763850790						

```
CONVERGENCE: REL_REDUCTION_OF_F_<=_FACTR*EPSMCH
```

```
[Parallel(n_jobs=1)]: Done 1 out of 1 | elapsed: 6.8s finished
```

```
[Parallel(n_jobs=1)]: Using backend SequentialBackend with 1 concurrent workers.
```

```
[Parallel(n_jobs=1)]: Done 1 out of 1 | elapsed: 6.7s finished
```

```
This problem is unconstrained.
```

```
* * *
```

```
Tit = total number of iterations
```

```
Tnf = total number of function evaluations
```

```
Tnint = total number of segments explored during Cauchy searches
```

```
Skip = number of BFGS updates skipped
```

```
Nact = number of active bounds at final generalized Cauchy point
```

```
Projg = norm of the final projected gradient
```

```
F = final function value
```

\* \* \*

N	Tit	Tnf	Tnint	Skip	Nact	Projg	F
66	344	387	1	0	0	1.021D+01	1.736D+05
F =	173627.41416011137						

CONVERGENCE: REL\_REDUCTION\_OF\_F\_<=\_FACTR\*EPSMCH  
RUNNING THE L-BFGS-B CODE

\* \* \*

Machine precision = 2.220D-16

N = 66 M = 10

At X0 0 variables are exactly at the bounds

At iterate 0 f= 2.00662D+05 |proj g|= 5.84398D+04

At iterate 350 f= 1.73613D+05 |proj g|= 8.62348D+01

RUNNING THE L-BFGS-B CODE

\* \* \*

Machine precision = 2.220D-16

N = 66 M = 10

At X0 0 variables are exactly at the bounds

At iterate 0 f= 2.00660D+05 |proj g|= 5.86870D+04

\* \* \*

Tit = total number of iterations

Tnf = total number of function evaluations

Tnint = total number of segments explored during Cauchy searches

Skip = number of BFGS updates skipped

Nact = number of active bounds at final generalized Cauchy point

Projg = norm of the final projected gradient

F = final function value

\* \* \*

N	Tit	Tnf	Tnint	Skip	Nact	Projg	F
66	338	376	1	0	0	3.177D+01	1.738D+05
F =	173773.11238188692						

CONVERGENCE: REL\_REDUCTION\_OF\_F\_<=\_FACTR\*EPSMCH

```
[Parallel(n_jobs=1)]: Using backend SequentialBackend with 1 concurrent workers.  
This problem is unconstrained.  
[Parallel(n_jobs=1)]: Done 1 out of 1 | elapsed: 6.6s finished  
[Parallel(n_jobs=1)]: Using backend SequentialBackend with 1 concurrent workers.  
This problem is unconstrained.
```

RUNNING THE L-BFGS-B CODE

\* \* \*

```
Machine precision = 2.220D-16  
N = 66 M = 10
```

At X0 0 variables are exactly at the bounds

At iterate 0 f= 2.00660D+05 |proj g|= 5.84726D+04

\* \* \*

```
Tit = total number of iterations  
Tnf = total number of function evaluations  
Tnint = total number of segments explored during Cauchy searches  
Skip = number of BFGS updates skipped  
Nact = number of active bounds at final generalized Cauchy point  
Projg = norm of the final projected gradient  
F = final function value
```

\* \* \*

N	Tit	Tnf	Tnint	Skip	Nact	Projg	F
66	370	414	1	0	0	1.029D+01	1.736D+05
F =	173613.34649771033						

CONVERGENCE: REL\_REDUCTION\_OF\_F\_<=\_FACTR\*EPSMCH

At iterate 50 f= 1.75181D+05 |proj g|= 2.54513D+03

```
[Parallel(n_jobs=1)]: Done 1 out of 1 | elapsed: 7.4s finished  
[Parallel(n_jobs=1)]: Using backend SequentialBackend with 1 concurrent workers.  
This problem is unconstrained.
```

RUNNING THE L-BFGS-B CODE

\* \* \*

```
Machine precision = 2.220D-16  
N = 66 M = 10
```

At X0 0 variables are exactly at the bounds

```

At iterate    0      f=  2.00660D+05      |proj g|=  5.86431D+04
At iterate   50      f=  1.75294D+05      |proj g|=  6.92237D+03
At iterate   50      f=  1.74896D+05      |proj g|=  2.42083D+03
At iterate  300      f=  1.73780D+05      |proj g|=  1.85281D+01
At iterate   50      f=  1.75260D+05      |proj g|=  7.76374D+03

```

\* \* \*

Tit = total number of iterations  
 Tnf = total number of function evaluations  
 Tnint = total number of segments explored during Cauchy searches  
 Skip = number of BFGS updates skipped  
 Nact = number of active bounds at final generalized Cauchy point  
 Projg = norm of the final projected gradient  
 F = final function value

\* \* \*

N	Tit	Tnf	Tnint	Skip	Nact	Projg	F
66	315	360	1	0	0	1.443D+01	1.738D+05
F =	173779.54872703785						

CONVERGENCE: REL\_REDUCTION\_OF\_F\_<=\_FACTR\*EPSMCH

```

At iterate   50      f=  1.74932D+05      |proj g|=  1.53723D+03
[Parallel(n_jobs=1)]: Done   1 out of   1 | elapsed:    6.3s finished
[Parallel(n_jobs=1)]: Using backend SequentialBackend with 1 concurrent workers.
This problem is unconstrained.

```

```

At iterate   50      f=  1.75035D+05      |proj g|=  1.50563D+04
RUNNING THE L-BFGS-B CODE

```

\* \* \*

Machine precision = 2.220D-16  
 N = 66 M = 10

At X0 0 variables are exactly at the bounds

```

At iterate    0      f=  2.00660D+05      |proj g|=  5.86808D+04
At iterate  100      f=  1.74246D+05      |proj g|=  1.18976D+04

```

At iterate	50	f= 1.74904D+05	proj g = 1.09138D+03
At iterate	100	f= 1.74071D+05	proj g = 1.02199D+03
At iterate	100	f= 1.73844D+05	proj g = 2.39430D+03
At iterate	100	f= 1.74215D+05	proj g = 1.48808D+03
At iterate	100	f= 1.74014D+05	proj g = 2.21706D+03
At iterate	100	f= 1.73885D+05	proj g = 2.77265D+03
At iterate	50	f= 1.75132D+05	proj g = 2.13400D+03
At iterate	150	f= 1.73853D+05	proj g = 5.93714D+02
At iterate	100	f= 1.74038D+05	proj g = 1.10949D+03
At iterate	150	f= 1.73707D+05	proj g = 3.46913D+03
At iterate	150	f= 1.73609D+05	proj g = 1.72070D+03
At iterate	150	f= 1.73785D+05	proj g = 5.39195D+02
At iterate	150	f= 1.73639D+05	proj g = 7.32840D+02
At iterate	150	f= 1.73601D+05	proj g = 3.83939D+02
At iterate	100	f= 1.74130D+05	proj g = 6.90270D+03
At iterate	150	f= 1.73665D+05	proj g = 1.40835D+03
At iterate	200	f= 1.73810D+05	proj g = 8.97499D+01
At iterate	200	f= 1.73672D+05	proj g = 2.04178D+02
At iterate	200	f= 1.73590D+05	proj g = 3.33894D+02
At iterate	200	f= 1.73726D+05	proj g = 2.44153D+02
At iterate	150	f= 1.73785D+05	proj g = 1.22661D+03
At iterate	200	f= 1.73612D+05	proj g = 2.86572D+02
At iterate	200	f= 1.73581D+05	proj g = 9.23125D+01
At iterate	250	f= 1.73805D+05	proj g = 1.60207D+02

```

At iterate 200      f= 1.73625D+05    |proj g|= 3.71699D+02
At iterate 250      f= 1.73664D+05    |proj g|= 2.64407D+02
At iterate 250      f= 1.73584D+05    |proj g|= 1.45098D+02
At iterate 250      f= 1.73718D+05    |proj g|= 2.17245D+02
At iterate 200      f= 1.73756D+05    |proj g|= 3.37581D+02
At iterate 250      f= 1.73605D+05    |proj g|= 1.26180D+02
At iterate 250      f= 1.73576D+05    |proj g|= 9.30573D+01
At iterate 300      f= 1.73803D+05    |proj g|= 8.01279D+01
At iterate 250      f= 1.73619D+05    |proj g|= 1.12009D+02
At iterate 300      f= 1.73662D+05    |proj g|= 1.27840D+02
At iterate 300      f= 1.73582D+05    |proj g|= 3.90029D+01
At iterate 300      f= 1.73715D+05    |proj g|= 9.37019D+01
At iterate 300      f= 1.73574D+05    |proj g|= 1.33290D+02
At iterate 300      f= 1.73603D+05    |proj g|= 1.15882D+02
At iterate 350      f= 1.73803D+05    |proj g|= 1.97864D+01
At iterate 300      f= 1.73617D+05    |proj g|= 4.23825D+01
At iterate 250      f= 1.73749D+05    |proj g|= 2.07355D+02

```

\* \* \*

Tit = total number of iterations  
 Tnf = total number of function evaluations  
 Tnint = total number of segments explored during Cauchy searches  
 Skip = number of BFGS updates skipped  
 Nact = number of active bounds at final generalized Cauchy point  
 Projg = norm of the final projected gradient  
 F = final function value

\* \* \*

N	Tit	Tnf	Tnint	Skip	Nact	Projg	F
---	-----	-----	-------	------	------	-------	---

66	337	375	1	0	0	2.411D+01	1.737D+05
F =	173662.21474314682						

CONVERGENCE: REL\_REDUCTION\_OF\_F\_<=\_FACTR\*EPSMCH  
 RUNNING THE L-BFGS-B CODE

\* \* \*

Machine precision = 2.220D-16

N =	66	M =	10
-----	----	-----	----

At X0 0 variables are exactly at the bounds

At iterate 0 f= 2.00662D+05 |proj g|= 5.81988D+04

[Parallel(n\_jobs=1)]: Done 1 out of 1 | elapsed: 7.0s finished  
 [Parallel(n\_jobs=1)]: Using backend SequentialBackend with 1 concurrent workers.  
 This problem is unconstrained.

At iterate 350 f= 1.73582D+05 |proj g|= 2.36265D+01

\* \* \*

Tit = total number of iterations

Tnf = total number of function evaluations

Tnint = total number of segments explored during Cauchy searches

Skip = number of BFGS updates skipped

Nact = number of active bounds at final generalized Cauchy point

Projg = norm of the final projected gradient

F = final function value

\* \* \*

N	Tit	Tnf	Tnint	Skip	Nact	Projg	F
66	335	361	1	0	0	1.002D+01	1.736D+05
F =	173617.13839482868						

CONVERGENCE: REL\_REDUCTION\_OF\_F\_<=\_FACTR\*EPSMCH

[Parallel(n\_jobs=1)]: Done 1 out of 1 | elapsed: 6.7s finished  
 [Parallel(n\_jobs=1)]: Using backend SequentialBackend with 1 concurrent workers.  
 [Parallel(n\_jobs=1)]: Done 1 out of 1 | elapsed: 7.3s finished  
 This problem is unconstrained.  
 [Parallel(n\_jobs=1)]: Using backend SequentialBackend with 1 concurrent workers.  
 This problem is unconstrained.

At iterate 350 f= 1.73715D+05 |proj g|= 1.42413D+01

\* \* \*

Tit = total number of iterations  
Tnf = total number of function evaluations  
Tnint = total number of segments explored during Cauchy searches  
Skip = number of BFGS updates skipped  
Nact = number of active bounds at final generalized Cauchy point  
Projg = norm of the final projected gradient  
F = final function value

\* \* \*

N	Tit	Tnf	Tnint	Skip	Nact	Projg	F
66	350	393	1	0	0	1.424D+01	1.737D+05
F =	173714.88716152587						

CONVERGENCE: REL\_REDUCTION\_OF\_F\_<=\_FACTR\*EPSMCH  
RUNNING THE L-BFGS-B CODE

\* \* \*

Machine precision = 2.220D-16

N = 66 M = 10

At X0 0 variables are exactly at the bounds

At iterate 0 f= 2.00662D+05 |proj g|= 5.86282D+04  
RUNNING THE L-BFGS-B CODE

\* \* \*

Machine precision = 2.220D-16

N = 66 M = 10

At X0 0 variables are exactly at the bounds

At iterate 0 f= 2.00662D+05 |proj g|= 5.80841D+04

At iterate 350 f= 1.73603D+05 |proj g|= 4.37968D+01

At iterate 350 f= 1.73574D+05 |proj g|= 2.13201D+01

At iterate 400 f= 1.73803D+05 |proj g|= 2.63722D+01

At iterate 300 f= 1.73747D+05 |proj g|= 4.68275D+01

At iterate 50 f= 1.75092D+05 |proj g|= 8.22067D+03

\* \* \*

Tit = total number of iterations  
Tnf = total number of function evaluations  
Tnint = total number of segments explored during Cauchy searches  
Skip = number of BFGS updates skipped  
Nact = number of active bounds at final generalized Cauchy point  
Projg = norm of the final projected gradient  
F = final function value

\* \* \*

N	Tit	Tnf	Tnint	Skip	Nact	Projg	F
66	360	402	1	0	0	8.024D+00	1.736D+05
F =	173602.83572221958						

CONVERGENCE: REL\_REDUCTION\_OF\_F\_<=\_FACTR\*EPSMCH

[Parallel(n\_jobs=1)]: Done 1 out of 1 | elapsed: 7.6s finished  
[Parallel(n\_jobs=1)]: Using backend SequentialBackend with 1 concurrent workers.  
This problem is unconstrained.

RUNNING THE L-BFGS-B CODE

\* \* \*

Machine precision = 2.220D-16  
N = 66 M = 10

At X0 0 variables are exactly at the bounds

At iterate 0 f= 2.00662D+05 |proj g|= 5.89084D+04

\* \* \*

Tit = total number of iterations  
Tnf = total number of function evaluations  
Tnint = total number of segments explored during Cauchy searches  
Skip = number of BFGS updates skipped  
Nact = number of active bounds at final generalized Cauchy point  
Projg = norm of the final projected gradient  
F = final function value

\* \* \*

N	Tit	Tnf	Tnint	Skip	Nact	Projg	F
66	393	443	1	0	0	5.839D+00	1.736D+05
F =	173581.80686853570						

```
CONVERGENCE: REL_REDUCTION_OF_F_<=_FACTR*EPSMCH
[Parallel(n_jobs=1)]: Done 1 out of 1 | elapsed: 8.3s finished
[Parallel(n_jobs=1)]: Using backend SequentialBackend with 1 concurrent workers.
This problem is unconstrained.
[Parallel(n_jobs=1)]: Done 1 out of 1 | elapsed: 8.8s finished
```

RUNNING THE L-BFGS-B CODE

\* \* \*

```
Machine precision = 2.220D-16
N = 66 M = 10
At X0 0 variables are exactly at the bounds
At iterate 0 f= 2.00662D+05 |proj g|= 5.84619D+04
```

\* \* \*

```
Tit = total number of iterations
Tnf = total number of function evaluations
Tnint = total number of segments explored during Cauchy searches
Skip = number of BFGS updates skipped
Nact = number of active bounds at final generalized Cauchy point
Projg = norm of the final projected gradient
F = final function value
```

\* \* \*

N	Tit	Tnf	Tnint	Skip	Nact	Projg	F
66	424	473	1	0	0	4.037D+01	1.738D+05
F =	173802.62112150269						

```
CONVERGENCE: REL_REDUCTION_OF_F_<=_FACTR*EPSMCH
RUNNING THE L-BFGS-B CODE
```

\* \* \*

```
Machine precision = 2.220D-16
N = 66 M = 10
At X0 0 variables are exactly at the bounds
At iterate 0 f= 2.00662D+05 |proj g|= 5.84398D+04
[Parallel(n_jobs=1)]: Using backend SequentialBackend with 1 concurrent workers.
This problem is unconstrained.
```

```

At iterate 50      f= 1.75148D+05    |proj g|= 6.81448D+03
At iterate 50      f= 1.75131D+05    |proj g|= 1.94212D+03
At iterate 400     f= 1.73574D+05    |proj g|= 1.86709D+01
At iterate 350     f= 1.73747D+05    |proj g|= 2.10535D+01

```

\* \* \*

Tit = total number of iterations  
 Tnf = total number of function evaluations  
 Tnint = total number of segments explored during Cauchy searches  
 Skip = number of BFGS updates skipped  
 Nact = number of active bounds at final generalized Cauchy point  
 Projg = norm of the final projected gradient  
 F = final function value

\* \* \*

N	Tit	Tnf	Tnint	Skip	Nact	Projg	F
66	405	455	1	0	0	1.018D+01	1.736D+05
F =	173573.60884588095						

CONVERGENCE: REL\_REDUCTION\_OF\_F\_<=\_FACTR\*EPSMCH

```

At iterate 100      f= 1.74194D+05    |proj g|= 1.61507D+03
[Parallel(n_jobs=1)]: Done   1 out of   1 | elapsed:    8.4s finished
[Parallel(n_jobs=1)]: Using backend SequentialBackend with 1 concurrent workers.
This problem is unconstrained.

```

RUNNING THE L-BFGS-B CODE

\* \* \*

Machine precision = 2.220D-16  
 N = 66 M = 10

At X0 0 variables are exactly at the bounds

At iterate 0 f= 2.00660D+05 |proj g|= 5.86870D+04

At iterate 50 f= 1.74922D+05 |proj g|= 1.60810D+03

\* \* \*

Tit = total number of iterations  
 Tnf = total number of function evaluations

Tnint = total number of segments explored during Cauchy searches  
 Skip = number of BFGS updates skipped  
 Nact = number of active bounds at final generalized Cauchy point  
 Projg = norm of the final projected gradient  
 F = final function value

\* \* \*

N	Tit	Tnf	Tnint	Skip	Nact	Projg	F
66	367	408	1	0	0	4.176D+01	1.737D+05
F = 173746.80881748724							

CONVERGENCE: REL\_REDUCTION\_OF\_F\_<=\_FACTR\*EPSMCH

[Parallel(n\_jobs=1)]: Done 1 out of 1 | elapsed: 7.7s finished  
 [Parallel(n\_jobs=1)]: Using backend SequentialBackend with 1 concurrent workers.  
 This problem is unconstrained.

RUNNING THE L-BFGS-B CODE

\* \* \*

Machine precision = 2.220D-16  
 N = 66 M = 10

At X0 0 variables are exactly at the bounds

At iterate 0 f= 2.00660D+05	proj g = 5.84726D+04
At iterate 50 f= 1.75117D+05	proj g = 5.83305D+03
At iterate 50 f= 1.75279D+05	proj g = 5.09087D+03
At iterate 100 f= 1.74141D+05	proj g = 6.03527D+03
At iterate 100 f= 1.74078D+05	proj g = 5.62588D+03
At iterate 150 f= 1.73812D+05	proj g = 8.52170D+02
At iterate 50 f= 1.74927D+05	proj g = 4.29875D+03
At iterate 100 f= 1.73906D+05	proj g = 5.66359D+03
At iterate 50 f= 1.75033D+05	proj g = 1.58224D+04
At iterate 100 f= 1.74200D+05	proj g = 3.08230D+03
At iterate 100 f= 1.74149D+05	proj g = 3.09695D+03

At iterate	150	f= 1.73810D+05	proj g = 6.96067D+02
At iterate	150	f= 1.73816D+05	proj g = 3.12664D+02
At iterate	200	f= 1.73772D+05	proj g = 1.18553D+02
At iterate	100	f= 1.74134D+05	proj g = 8.64109D+02
At iterate	150	f= 1.73609D+05	proj g = 4.19133D+02
At iterate	100	f= 1.73970D+05	proj g = 2.19314D+03
At iterate	150	f= 1.73708D+05	proj g = 1.25212D+03
At iterate	150	f= 1.73739D+05	proj g = 2.22028D+03
At iterate	200	f= 1.73778D+05	proj g = 3.17801D+02
At iterate	200	f= 1.73799D+05	proj g = 3.61923D+02
At iterate	150	f= 1.73673D+05	proj g = 5.66079D+02
At iterate	250	f= 1.73764D+05	proj g = 3.90677D+02
At iterate	200	f= 1.73581D+05	proj g = 3.19966D+02
At iterate	150	f= 1.73625D+05	proj g = 7.64267D+02
At iterate	200	f= 1.73713D+05	proj g = 2.07547D+02
At iterate	200	f= 1.73673D+05	proj g = 1.95273D+02
At iterate	250	f= 1.73771D+05	proj g = 6.31320D+01
At iterate	250	f= 1.73793D+05	proj g = 1.53738D+02
At iterate	300	f= 1.73763D+05	proj g = 4.43001D+01
At iterate	200	f= 1.73613D+05	proj g = 1.89823D+02
At iterate	250	f= 1.73574D+05	proj g = 1.32124D+02
At iterate	200	f= 1.73586D+05	proj g = 4.00092D+02
At iterate	250	f= 1.73707D+05	proj g = 1.81299D+02

\* \* \*

Tit = total number of iterations  
 Tnf = total number of function evaluations  
 Tnint = total number of segments explored during Cauchy searches  
 Skip = number of BFGS updates skipped  
 Nact = number of active bounds at final generalized Cauchy point  
 Projg = norm of the final projected gradient  
 F = final function value

\* \* \*

N	Tit	Tnf	Tnint	Skip	Nact	Projg	F
66	323	367	1	0	0	1.573D+01	1.738D+05
F =	173762.75918580184						

CONVERGENCE: REL\_REDUCTION\_OF\_F\_<=\_FACTR\*EPSMCH

At iterate 250 f= 1.73653D+05 |proj g|= 2.71387D+02  
 [Parallel(n\_jobs=1)]: Done 1 out of 1 | elapsed: 6.6s finished  
 [Parallel(n\_jobs=1)]: Using backend SequentialBackend with 1 concurrent workers.  
 This problem is unconstrained.

At iterate 300 f= 1.73792D+05 |proj g|= 3.52695D+01

At iterate 300 f= 1.73770D+05 |proj g|= 3.65609D+01  
 RUNNING THE L-BFGS-B CODE

\* \* \*

Machine precision = 2.220D-16  
 N = 66 M = 10

At X0 0 variables are exactly at the bounds

At iterate 0 f= 2.00660D+05 |proj g|= 5.86431D+04

At iterate 250 f= 1.73606D+05 |proj g|= 1.86818D+02

At iterate 300 f= 1.73571D+05 |proj g|= 3.98751D+01

\* \* \*

Tit = total number of iterations  
 Tnf = total number of function evaluations  
 Tnint = total number of segments explored during Cauchy searches  
 Skip = number of BFGS updates skipped  
 Nact = number of active bounds at final generalized Cauchy point  
 Projg = norm of the final projected gradient

F = final function value

\* \* \*

N	Tit	Tnf	Tnint	Skip	Nact	Projg	F
66	335	375	1	0	0	3.009D+01	1.738D+05
F =	173792.06632607698						

CONVERGENCE: REL\_REDUCTION\_OF\_F\_<=\_FACTR\*EPSMCH

At iterate 250 f= 1.73579D+05 |proj g|= 1.38403D+02  
RUNNING THE L-BFGS-B CODE

\* \* \*

Machine precision = 2.220D-16

N = 66 M = 10

At X0 0 variables are exactly at the bounds

At iterate 0 f= 2.00660D+05 |proj g|= 5.86808D+04

[Parallel(n\_jobs=1)]: Done 1 out of 1 | elapsed: 6.7s finished  
[Parallel(n\_jobs=1)]: Using backend SequentialBackend with 1 concurrent workers.  
This problem is unconstrained.

At iterate 300 f= 1.73652D+05 |proj g|= 1.20472D+02

At iterate 300 f= 1.73705D+05 |proj g|= 4.66017D+01

At iterate 50 f= 1.74930D+05 |proj g|= 3.73595D+03

At iterate 350 f= 1.73769D+05 |proj g|= 4.19030D+01

\* \* \*

Tit = total number of iterations

Tnf = total number of function evaluations

Tnint = total number of segments explored during Cauchy searches

Skip = number of BFGS updates skipped

Nact = number of active bounds at final generalized Cauchy point

Projg = norm of the final projected gradient

F = final function value

\* \* \*

N	Tit	Tnf	Tnint	Skip	Nact	Projg	F
66	307	353	1	0	0	5.656D+01	1.737D+05

F = 173651.50843656244

CONVERGENCE: REL\_REDUCTION\_OF\_F\_<=\_FACTR\*EPSMCH

[Parallel(n\_jobs=1)]: Done 1 out of 1 | elapsed: 6.4s finished  
[Parallel(n\_jobs=1)]: Using backend SequentialBackend with 1 concurrent workers.  
This problem is unconstrained.

RUNNING THE L-BFGS-B CODE

\* \* \*

Machine precision = 2.220D-16

N = 66 M = 10

At X0 0 variables are exactly at the bounds

At iterate 0 f= 2.00662D+05 |proj g|= 5.81988D+04

\* \* \*

Tit = total number of iterations

Tnf = total number of function evaluations

Tnint = total number of segments explored during Cauchy searches

Skip = number of BFGS updates skipped

Nact = number of active bounds at final generalized Cauchy point

Projg = norm of the final projected gradient

F = final function value

\* \* \*

N	Tit	Tnf	Tnint	Skip	Nact	Projg	F
66	362	410	1	0	0	4.468D+01	1.738D+05
F =	173769.30412194927						

CONVERGENCE: REL\_REDUCTION\_OF\_F\_<=\_FACTR\*EPSMCH

\* \* \*

Tit = total number of iterations

Tnf = total number of function evaluations

Tnint = total number of segments explored during Cauchy searches

Skip = number of BFGS updates skipped

Nact = number of active bounds at final generalized Cauchy point

Projg = norm of the final projected gradient

F = final function value

\* \* \*

N	Tit	Tnf	Tnint	Skip	Nact	Projg	F
66	340	383	1	0	0	2.529D+01	1.736D+05
F =	173570.77223716924						

CONVERGENCE: REL\_REDUCTION\_OF\_F\_<=\_FACTR\*EPSMCH

[Parallel(n\_jobs=1)]: Done 1 out of 1 | elapsed: 7.4s finished  
 [Parallel(n\_jobs=1)]: Done 1 out of 1 | elapsed: 7.0s finished  
 [Parallel(n\_jobs=1)]: Using backend SequentialBackend with 1 concurrent workers.  
 [Parallel(n\_jobs=1)]: Using backend SequentialBackend with 1 concurrent workers.  
 This problem is unconstrained.  
 This problem is unconstrained.

At iterate 300 f= 1.73602D+05 |proj g|= 4.58606D+01  
 RUNNING THE L-BFGS-B CODE

\* \* \*

Machine precision = 2.220D-16  
 N = 66 M = 10

At X0 0 variables are exactly at the bounds

At iterate 0 f= 2.00662D+05 |proj g|= 5.86282D+04  
 RUNNING THE L-BFGS-B CODE

\* \* \*

Machine precision = 2.220D-16  
 N = 66 M = 10

At X0 0 variables are exactly at the bounds

At iterate 0 f= 2.00662D+05 |proj g|= 5.80841D+04

At iterate 50 f= 1.75092D+05 |proj g|= 2.56856D+03

At iterate 300 f= 1.73573D+05 |proj g|= 9.61441D+01

At iterate 100 f= 1.73830D+05 |proj g|= 6.88900D+02

At iterate 350 f= 1.73705D+05 |proj g|= 6.72685D+01

\* \* \*

Tit = total number of iterations

Tnf = total number of function evaluations

Tnint = total number of segments explored during Cauchy searches

Skip = number of BFGS updates skipped  
 Nact = number of active bounds at final generalized Cauchy point  
 Projg = norm of the final projected gradient  
 F = final function value

\* \* \*

N	Tit	Tnf	Tnint	Skip	Nact	Projg	F
66	355	391	1	0	0	4.629D+01	1.737D+05
F =	173704.54872902471						

CONVERGENCE: REL\_REDUCTION\_OF\_F\_<=\_FACTR\*EPSMCH

At iterate 50 f= 1.75138D+05 |proj g|= 1.37849D+04  
 RUNNING THE L-BFGS-B CODE

\* \* \*

Machine precision = 2.220D-16  
 N = 66 M = 10

At X0 0 variables are exactly at the bounds

At iterate 0 f= 2.00662D+05 |proj g|= 5.89084D+04

[Parallel(n\_jobs=1)]: Done 1 out of 1 | elapsed: 7.3s finished  
 [Parallel(n\_jobs=1)]: Using backend SequentialBackend with 1 concurrent workers.  
 This problem is unconstrained.

At iterate 350 f= 1.73602D+05 |proj g|= 5.07886D+01

\* \* \*

Tit = total number of iterations  
 Tnf = total number of function evaluations  
 Tnint = total number of segments explored during Cauchy searches  
 Skip = number of BFGS updates skipped  
 Nact = number of active bounds at final generalized Cauchy point  
 Projg = norm of the final projected gradient  
 F = final function value

\* \* \*

N	Tit	Tnf	Tnint	Skip	Nact	Projg	F
66	353	391	1	0	0	8.403D+00	1.736D+05
F =	173601.79348821967						

CONVERGENCE: REL\_REDUCTION\_OF\_F\_<=\_FACTR\*EPSMCH

At iterate 50 f= 1.75161D+05 |proj g|= 5.81378D+03

At iterate 50 f= 1.75142D+05 |proj g|= 2.02160D+03  
RUNNING THE L-BFGS-B CODE

\* \* \*

Machine precision = 2.220D-16

N = 66 M = 10

At X0 0 variables are exactly at the bounds

At iterate 0 f= 2.00662D+05 |proj g|= 5.84619D+04

[Parallel(n\_jobs=1)]: Done 1 out of 1 | elapsed: 7.1s finished  
[Parallel(n\_jobs=1)]: Using backend SequentialBackend with 1 concurrent workers.  
This problem is unconstrained.

\* \* \*

Tit = total number of iterations

Tnf = total number of function evaluations

Tnint = total number of segments explored during Cauchy searches

Skip = number of BFGS updates skipped

Nact = number of active bounds at final generalized Cauchy point

Projg = norm of the final projected gradient

F = final function value

\* \* \*

N	Tit	Tnf	Tnint	Skip	Nact	Projg	F
66	340	389	1	0	0	6.986D+00	1.736D+05
F =	173572.49479208820						

CONVERGENCE: REL\_REDUCTION\_OF\_F\_<=\_FACTR\*EPSMCH

At iterate 100 f= 1.74152D+05 |proj g|= 4.32862D+03  
RUNNING THE L-BFGS-B CODE

\* \* \*

Machine precision = 2.220D-16

N = 66 M = 10

At X0 0 variables are exactly at the bounds

At iterate 0 f= 2.00662D+05 |proj g|= 5.84398D+04

```
[Parallel(n_jobs=1)]: Done    1 out of    1 | elapsed:    7.1s finished
[Parallel(n_jobs=1)]: Using backend SequentialBackend with 1 concurrent workers.
This problem is unconstrained.
```

```
At iterate  150    f=  1.73633D+05    |proj g|=  2.91526D+02
At iterate  100    f=  1.74095D+05    |proj g|=  3.59433D+03
At iterate   50    f=  1.74966D+05    |proj g|=  3.44674D+03
At iterate  100    f=  1.74105D+05    |proj g|=  1.00104D+03
At iterate  100    f=  1.74116D+05    |proj g|=  1.06145D+03
At iterate   50    f=  1.75078D+05    |proj g|=  3.35208D+03
At iterate  150    f=  1.73784D+05    |proj g|=  1.20639D+03
At iterate   50    f=  1.75131D+05    |proj g|=  7.36650D+03
At iterate  200    f=  1.73622D+05    |proj g|=  1.17988D+02
At iterate  100    f=  1.73891D+05    |proj g|=  6.60645D+03
At iterate  150    f=  1.73800D+05    |proj g|=  2.53540D+03
At iterate  150    f=  1.73833D+05    |proj g|=  5.96394D+02
At iterate  150    f=  1.73793D+05    |proj g|=  2.39381D+03
At iterate  100    f=  1.74048D+05    |proj g|=  1.11631D+03
At iterate  200    f=  1.73755D+05    |proj g|=  2.79952D+02
At iterate  100    f=  1.74268D+05    |proj g|=  1.46492D+03
At iterate  250    f=  1.73617D+05    |proj g|=  4.14209D+01
At iterate  150    f=  1.73621D+05    |proj g|=  2.05682D+03
At iterate  200    f=  1.73771D+05    |proj g|=  1.74795D+02
At iterate  200    f=  1.73803D+05    |proj g|=  3.50870D+02
At iterate  200    f=  1.73775D+05    |proj g|=  2.36858D+02
At iterate  150    f=  1.73690D+05    |proj g|=  3.79439D+03
```

```

At iterate 150      f= 1.73774D+05      |proj g|= 1.95681D+03
At iterate 250      f= 1.73748D+05      |proj g|= 4.30604D+01
* * *
Tit = total number of iterations
Tnf = total number of function evaluations
Tnint = total number of segments explored during Cauchy searches
Skip = number of BFGS updates skipped
Nact = number of active bounds at final generalized Cauchy point
Projg = norm of the final projected gradient
F = final function value

```

\* \* \*

N	Tit	Tnf	Tnint	Skip	Nact	Projg	F
66	297	338	1	0	0	5.608D+01	1.736D+05
F = 173616.15923917139							

CONVERGENCE: REL\_REDUCTION\_OF\_F\_<=\_FACTR\*EPSMCH

```

At iterate 250      f= 1.73765D+05      |proj g|= 5.87582D+02
RUNNING THE L-BFGS-B CODE

```

\* \* \*

```

Machine precision = 2.220D-16
N =           66      M =           10

```

At X0 0 variables are exactly at the bounds

```

At iterate 0      f= 2.00660D+05      |proj g|= 5.86870D+04

```

```

At iterate 200     f= 1.73580D+05      |proj g|= 3.00529D+02

```

```

[Parallel(n_jobs=1)]: Done   1 out of   1 | elapsed:    6.1s finished
[Parallel(n_jobs=1)]: Using backend SequentialBackend with 1 concurrent workers.
This problem is unconstrained.

```

```

At iterate 250     f= 1.73793D+05      |proj g|= 2.52544D+02

```

```

At iterate 250     f= 1.73770D+05      |proj g|= 8.17065D+01

```

```

At iterate 200     f= 1.73659D+05      |proj g|= 2.46133D+02

```

```

At iterate 200     f= 1.73714D+05      |proj g|= 2.09023D+02

```

```

At iterate 300    f= 1.73746D+05  |proj g|= 1.74312D+02
At iterate 300    f= 1.73763D+05  |proj g|= 1.72906D+02
At iterate 50     f= 1.74930D+05  |proj g|= 4.54254D+03
At iterate 250    f= 1.73573D+05  |proj g|= 1.39287D+02
At iterate 300    f= 1.73768D+05  |proj g|= 3.20171D+01
At iterate 300    f= 1.73791D+05  |proj g|= 1.00777D+02
At iterate 250    f= 1.73652D+05  |proj g|= 5.35021D+02
At iterate 250    f= 1.73706D+05  |proj g|= 3.16124D+02
At iterate 350    f= 1.73746D+05  |proj g|= 1.91755D+01
At iterate 350    f= 1.73762D+05  |proj g|= 2.65974D+01
At iterate 100    f= 1.73957D+05  |proj g|= 1.58640D+03
At iterate 300    f= 1.73570D+05  |proj g|= 3.68922D+01

```

\* \* \*

Tit = total number of iterations  
 Tnf = total number of function evaluations  
 Tnint = total number of segments explored during Cauchy searches  
 Skip = number of BFGS updates skipped  
 Nact = number of active bounds at final generalized Cauchy point  
 Projg = norm of the final projected gradient  
 F = final function value

\* \* \*

N	Tit	Tnf	Tnint	Skip	Nact	Projg	F
66	337	377	1	0	0	2.648D+01	1.738D+05
F =	173790.97699443350						

CONVERGENCE: REL\_REDUCTION\_OF\_F\_<=\_FACTR\*EPSMCH

[Parallel(n\_jobs=1)]: Done 1 out of 1 | elapsed: 6.9s finished  
 [Parallel(n\_jobs=1)]: Using backend SequentialBackend with 1 concurrent workers.  
 This problem is unconstrained.  
 [Parallel(n\_jobs=1)]: Done 1 out of 1 | elapsed: 7.0s finished  
 [Parallel(n\_jobs=1)]: Using backend SequentialBackend with 1 concurrent workers.

RUNNING THE L-BFGS-B CODE

\* \* \*

Machine precision = 2.220D-16  
N = 66 M = 10

At X0 0 variables are exactly at the bounds

At iterate 0 f= 2.00660D+05 |proj g|= 5.84726D+04

\* \* \*

Tit = total number of iterations  
Tnf = total number of function evaluations  
Tnint = total number of segments explored during Cauchy searches  
Skip = number of BFGS updates skipped  
Nact = number of active bounds at final generalized Cauchy point  
Projg = norm of the final projected gradient  
F = final function value

\* \* \*

N	Tit	Tnf	Tnint	Skip	Nact	Projg	F
66	347	390	1	0	0	4.629D+01	1.738D+05
F =	173768.23559859613						

CONVERGENCE: REL\_REDUCTION\_OF\_F\_<=\_FACTR\*EPSMCH  
RUNNING THE L-BFGS-B CODE

\* \* \*

Machine precision = 2.220D-16  
N = 66 M = 10

At X0 0 variables are exactly at the bounds

At iterate 0 f= 2.00660D+05 |proj g|= 5.86431D+04

This problem is unconstrained.  
[Parallel(n\_jobs=1)]: Done 1 out of 1 | elapsed: 7.9s finished

\* \* \*

Tit = total number of iterations  
Tnf = total number of function evaluations  
Tnint = total number of segments explored during Cauchy searches  
Skip = number of BFGS updates skipped

Nact = number of active bounds at final generalized Cauchy point  
 Projg = norm of the final projected gradient  
 F = final function value

\* \* \*

N	Tit	Tnf	Tnint	Skip	Nact	Projg	F
66	386	430	1	0	0	6.548D+00	1.737D+05
F =	173745.73737756183						

CONVERGENCE: REL\_REDUCTION\_OF\_F\_<=\_FACTR\*EPSMCH

At iterate 300 f= 1.73650D+05 |proj g|= 4.59672D+01  
 RUNNING THE L-BFGS-B CODE

\* \* \*

Machine precision = 2.220D-16

N = 66 M = 10

At X0 0 variables are exactly at the bounds

At iterate 0 f= 2.00660D+05 |proj g|= 5.86808D+04

[Parallel(n\_jobs=1)]: Using backend SequentialBackend with 1 concurrent workers.  
 This problem is unconstrained.

At iterate 300 f= 1.73704D+05 |proj g|= 6.91067D+01

At iterate 400 f= 1.73762D+05 |proj g|= 3.51537D+01

At iterate 150 f= 1.73640D+05 |proj g|= 8.71803D+02

At iterate 350 f= 1.73570D+05 |proj g|= 4.07579D+01

\* \* \*

Tit = total number of iterations

Tnf = total number of function evaluations

Tnint = total number of segments explored during Cauchy searches

Skip = number of BFGS updates skipped

Nact = number of active bounds at final generalized Cauchy point

Projg = norm of the final projected gradient

F = final function value

\* \* \*

N	Tit	Tnf	Tnint	Skip	Nact	Projg	F
---	-----	-----	-------	------	------	-------	---

```
66      334      374      1      0      0    3.786D+01    1.737D+05  
F = 173650.35098017598
```

CONVERGENCE: REL\_REDUCTION\_OF\_F\_<=\_FACTR\*EPSMCH

At iterate 50 f= 1.75032D+05 |proj g|= 1.59153D+04

\* \* \*

Tit = total number of iterations  
Tnf = total number of function evaluations  
Tnint = total number of segments explored during Cauchy searches  
Skip = number of BFGS updates skipped  
Nact = number of active bounds at final generalized Cauchy point  
Projg = norm of the final projected gradient  
F = final function value

\* \* \*

N	Tit	Tnf	Tnint	Skip	Nact	Projg	F
66	415	454	1	0	0	9.112D+00	1.738D+05
F							173761.72527015879

CONVERGENCE: REL\_REDUCTION\_OF\_F\_<=\_FACTR\*EPSMCH  
RUNNING THE L-BFGS-B CODE

\* \* \*

Machine precision = 2.220D-16

N = 66 M = 10

At X0 0 variables are exactly at the bounds

At iterate 0 f= 2.00662D+05 |proj g|= 5.81988D+04

At iterate 50 f= 1.74922D+05 |proj g|= 2.65646D+03

RUNNING THE L-BFGS-B CODE

\* \* \*

Machine precision = 2.220D-16

N = 66 M = 10

At X0 0 variables are exactly at the bounds

At iterate 0 f= 2.00662D+05 |proj g|= 5.86282D+04

[Parallel(n\_jobs=1)]: Done 1 out of 1 | elapsed: 6.8s finished

```
[Parallel(n_jobs=1)]: Done 1 out of 1 | elapsed: 8.3s finished
[Parallel(n_jobs=1)]: Using backend SequentialBackend with 1 concurrent workers.
This problem is unconstrained.
[Parallel(n_jobs=1)]: Using backend SequentialBackend with 1 concurrent workers.
This problem is unconstrained.
```

```
At iterate 50 f= 1.75089D+05 |proj g|= 4.57858D+03
At iterate 350 f= 1.73703D+05 |proj g|= 2.14674D+01
At iterate 400 f= 1.73570D+05 |proj g|= 1.20050D+02
```

\* \* \*

```
Tit = total number of iterations
Tnf = total number of function evaluations
Tnint = total number of segments explored during Cauchy searches
Skip = number of BFGS updates skipped
Nact = number of active bounds at final generalized Cauchy point
Projg = norm of the final projected gradient
F = final function value
```

\* \* \*

N	Tit	Tnf	Tnint	Skip	Nact	Projg	F
66	369	409	1	0	0	1.945D+01	1.737D+05
F =	173703.46093316344						

CONVERGENCE: REL\_REDUCTION\_OF\_F\_<=\_FACTR\*EPSMCH

```
At iterate 200 f= 1.73611D+05 |proj g|= 1.00793D+02
RUNNING THE L-BFGS-B CODE
```

\* \* \*

```
Machine precision = 2.220D-16
N = 66 M = 10
```

At X0 0 variables are exactly at the bounds

```
At iterate 0 f= 2.00662D+05 |proj g|= 5.80841D+04
```

```
[Parallel(n_jobs=1)]: Done 1 out of 1 | elapsed: 7.5s finished
[Parallel(n_jobs=1)]: Using backend SequentialBackend with 1 concurrent workers.
This problem is unconstrained.
```

```
At iterate 100 f= 1.73945D+05 |proj g|= 5.47557D+03
```

```

At iterate 50      f= 1.75140D+05    |proj g|= 1.40824D+04
At iterate 50      f= 1.75156D+05    |proj g|= 6.76458D+03
At iterate 100     f= 1.74080D+05    |proj g|= 5.16038D+03

```

\* \* \*

Tit = total number of iterations  
 Tnf = total number of function evaluations  
 Tnint = total number of segments explored during Cauchy searches  
 Skip = number of BFGS updates skipped  
 Nact = number of active bounds at final generalized Cauchy point  
 Projg = norm of the final projected gradient  
 F = final function value

\* \* \*

N	Tit	Tnf	Tnint	Skip	Nact	Projg	F
66	417	461	1	0	0	3.340D+01	1.736D+05
F = 173569.57048700372							

CONVERGENCE: REL\_REDUCTION\_OF\_F\_<=\_FACTR\*EPSMCH

[Parallel(n\_jobs=1)]: Done 1 out of 1 | elapsed: 8.4s finished  
 [Parallel(n\_jobs=1)]: Using backend SequentialBackend with 1 concurrent workers.  
 This problem is unconstrained.

RUNNING THE L-BFGS-B CODE

\* \* \*

Machine precision = 2.220D-16  
 N = 66 M = 10

At X0 0 variables are exactly at the bounds

```

At iterate 0      f= 2.00662D+05    |proj g|= 5.89084D+04
At iterate 100    f= 1.74002D+05    |proj g|= 2.96732D+03
At iterate 250    f= 1.73604D+05    |proj g|= 9.66587D+01
At iterate 50      f= 1.75143D+05    |proj g|= 1.96886D+03
At iterate 150    f= 1.73625D+05    |proj g|= 1.27863D+03
At iterate 100    f= 1.73999D+05    |proj g|= 7.36697D+02

```

```

At iterate 100    f= 1.74177D+05  |proj g|= 1.19902D+03
At iterate 150    f= 1.73678D+05  |proj g|= 4.06626D+02
At iterate 150    f= 1.73769D+05  |proj g|= 5.85736D+02
At iterate 50     f= 1.74934D+05  |proj g|= 3.85155D+03
At iterate 300    f= 1.73602D+05  |proj g|= 6.26932D+01
At iterate 100    f= 1.74165D+05  |proj g|= 1.18316D+03
At iterate 150    f= 1.73783D+05  |proj g|= 8.90070D+02
At iterate 200    f= 1.73583D+05  |proj g|= 3.49278D+02
At iterate 150    f= 1.73825D+05  |proj g|= 1.08991D+03
At iterate 200    f= 1.73625D+05  |proj g|= 2.55112D+02
At iterate 100    f= 1.73928D+05  |proj g|= 2.88209D+03
At iterate 200    f= 1.73752D+05  |proj g|= 4.43890D+02
At iterate 350    f= 1.73602D+05  |proj g|= 2.16172D+01
At iterate 150    f= 1.73822D+05  |proj g|= 1.91547D+03
At iterate 250    f= 1.73575D+05  |proj g|= 1.58630D+02
At iterate 200    f= 1.73769D+05  |proj g|= 4.20854D+02
At iterate 200    f= 1.73777D+05  |proj g|= 2.26492D+02
At iterate 250    f= 1.73618D+05  |proj g|= 7.81465D+01
At iterate 150    f= 1.73609D+05  |proj g|= 5.63609D+02
At iterate 250    f= 1.73747D+05  |proj g|= 3.04725D+02

```

\* \* \*

Tit = total number of iterations  
 Tnf = total number of function evaluations  
 Tnint = total number of segments explored during Cauchy searches  
 Skip = number of BFGS updates skipped  
 Nact = number of active bounds at final generalized Cauchy point

Projg = norm of the final projected gradient  
F = final function value

\* \* \*

N	Tit	Tnf	Tnint	Skip	Nact	Projg	F
66	381	426	1	0	0	9.130D+00	1.736D+05
F =	173601.63233038542						

CONVERGENCE: REL\_REDUCTION\_OF\_F\_<=\_FACTR\*EPSMCH  
RUNNING THE L-BFGS-B CODE

\* \* \*

Machine precision = 2.220D-16

N = 66 M = 10

At X0 0 variables are exactly at the bounds

At iterate 0 f= 2.00662D+05 |proj g|= 5.84619D+04

[Parallel(n\_jobs=1)]: Done 1 out of 1 | elapsed: 7.7s finished

[Parallel(n\_jobs=1)]: Using backend SequentialBackend with 1 concurrent workers.  
This problem is unconstrained.

At iterate 200 f= 1.73799D+05 |proj g|= 6.62837D+01

At iterate 250 f= 1.73763D+05 |proj g|= 5.14665D+01

At iterate 300 f= 1.73573D+05 |proj g|= 1.26994D+02

At iterate 250 f= 1.73771D+05 |proj g|= 1.34078D+02

At iterate 300 f= 1.73616D+05 |proj g|= 1.26633D+02

At iterate 200 f= 1.73582D+05 |proj g|= 1.65914D+02

At iterate 300 f= 1.73746D+05 |proj g|= 2.29966D+01

At iterate 50 f= 1.75055D+05 |proj g|= 1.76137D+03

\* \* \*

Tit = total number of iterations

Tnf = total number of function evaluations

Tnint = total number of segments explored during Cauchy searches

Skip = number of BFGS updates skipped

Nact = number of active bounds at final generalized Cauchy point

Projg = norm of the final projected gradient  
F = final function value

\* \* \*

N	Tit	Tnf	Tnint	Skip	Nact	Projg	F
66	314	358	1	0	0	2.697D+01	1.737D+05
F =	173745.66811542949						

CONVERGENCE: REL\_REDUCTION\_OF\_F\_<=\_FACTR\*EPSMCH

At iterate 250 f= 1.73793D+05 |proj g|= 2.90916D+02  
RUNNING THE L-BFGS-B CODE

\* \* \*

Machine precision = 2.220D-16

N = 66 M = 10

At X0 0 variables are exactly at the bounds

At iterate 0 f= 2.00662D+05 |proj g|= 5.84398D+04

[Parallel(n\_jobs=1)]: Done 1 out of 1 | elapsed: 6.6s finished  
[Parallel(n\_jobs=1)]: Using backend SequentialBackend with 1 concurrent workers.  
This problem is unconstrained.

At iterate 300 f= 1.73762D+05 |proj g|= 3.84151D+01

At iterate 300 f= 1.73768D+05 |proj g|= 4.23648D+01

At iterate 350 f= 1.73573D+05 |proj g|= 2.90675D+01

At iterate 250 f= 1.73573D+05 |proj g|= 2.38001D+02

At iterate 350 f= 1.73616D+05 |proj g|= 3.93795D+01

At iterate 100 f= 1.73997D+05 |proj g|= 1.88432D+03

\* \* \*

Tit = total number of iterations

Tnf = total number of function evaluations

Tnint = total number of segments explored during Cauchy searches

Skip = number of BFGS updates skipped

Nact = number of active bounds at final generalized Cauchy point

Projg = norm of the final projected gradient

F = final function value

\* \* \*

N	Tit	Tnf	Tnint	Skip	Nact	Projg	F
66	317	354	1	0	0	2.593D+01	1.738D+05
F =	173761.70718920691						

CONVERGENCE: REL\_REDUCTION\_OF\_F\_<=\_FACTR\*EPSMCH

[Parallel(n\_jobs=1)]: Done 1 out of 1 | elapsed: 6.6s finished

At iterate 50	f= 1.75129D+05	proj g = 7.18178D+03
At iterate 300	f= 1.73791D+05	proj g = 8.88517D+01
At iterate 350	f= 1.73768D+05	proj g = 1.72590D+01
At iterate 400	f= 1.73572D+05	proj g = 4.85557D+01
At iterate 300	f= 1.73570D+05	proj g = 2.92352D+01
At iterate 150	f= 1.73701D+05	proj g = 8.95764D+02
At iterate 400	f= 1.73616D+05	proj g = 1.46682D+01

\* \* \*

Tit = total number of iterations

Tnf = total number of function evaluations

Tnint = total number of segments explored during Cauchy searches

Skip = number of BFGS updates skipped

Nact = number of active bounds at final generalized Cauchy point

Projg = norm of the final projected gradient

F = final function value

\* \* \*

N	Tit	Tnf	Tnint	Skip	Nact	Projg	F
66	380	421	1	0	0	2.510D+01	1.738D+05
F =	173768.06557992595						

CONVERGENCE: REL\_REDUCTION\_OF\_F\_<=\_FACTR\*EPSMCH

\* \* \*

Tit = total number of iterations

Tnf = total number of function evaluations

Tnint = total number of segments explored during Cauchy searches

Skip = number of BFGS updates skipped  
 Nact = number of active bounds at final generalized Cauchy point  
 Projg = norm of the final projected gradient  
 F = final function value

\* \* \*

N	Tit	Tnf	Tnint	Skip	Nact	Projg	F
66	432	480	1	0	0	1.186D+01	1.736D+05
F =	173572.39043878019						

CONVERGENCE: REL\_REDUCTION\_OF\_F\_<=\_FACTR\*EPSMCH

At iterate 100 f= 1.74074D+05 |proj g|= 7.16307D+02  
 At iterate 350 f= 1.73791D+05 |proj g|= 1.22586D+01

\* \* \*

Tit = total number of iterations  
 Tnf = total number of function evaluations  
 Tnint = total number of segments explored during Cauchy searches  
 Skip = number of BFGS updates skipped  
 Nact = number of active bounds at final generalized Cauchy point  
 Projg = norm of the final projected gradient  
 F = final function value

\* \* \*

N	Tit	Tnf	Tnint	Skip	Nact	Projg	F
66	352	392	1	0	0	2.205D+01	1.738D+05
F =	173790.89023821708						

CONVERGENCE: REL\_REDUCTION\_OF\_F\_<=\_FACTR\*EPSMCH

[Parallel(n\_jobs=1)]: Done 1 out of 1 | elapsed: 7.6s finished  
 [Parallel(n\_jobs=1)]: Done 1 out of 1 | elapsed: 8.8s finished  
 [Parallel(n\_jobs=1)]: Done 1 out of 1 | elapsed: 7.0s finished

\* \* \*

Tit = total number of iterations  
 Tnf = total number of function evaluations  
 Tnint = total number of segments explored during Cauchy searches  
 Skip = number of BFGS updates skipped  
 Nact = number of active bounds at final generalized Cauchy point  
 Projg = norm of the final projected gradient  
 F = final function value

\* \* \*

N	Tit	Tnf	Tnint	Skip	Nact	Projg	F
66	426	480	1	0	0	1.077D+01	1.736D+05
F =	173615.97305320521						

CONVERGENCE: REL\_REDUCTION\_OF\_F\_<=\_FACTR\*EPSMCH

[Parallel(n\_jobs=1)]: Done 1 out of 1 | elapsed: 8.9s finished

At iterate 350	f= 1.73570D+05	proj g = 5.40763D+01
At iterate 200	f= 1.73662D+05	proj g = 7.41808D+02
At iterate 150	f= 1.73761D+05	proj g = 1.18845D+03

\* \* \*

Tit = total number of iterations

Tnf = total number of function evaluations

Tnint = total number of segments explored during Cauchy searches

Skip = number of BFGS updates skipped

Nact = number of active bounds at final generalized Cauchy point

Projg = norm of the final projected gradient

F = final function value

\* \* \*

N	Tit	Tnf	Tnint	Skip	Nact	Projg	F
66	375	415	1	0	0	8.776D+00	1.736D+05
F =	173569.50003432174						

CONVERGENCE: REL\_REDUCTION\_OF\_F\_<=\_FACTR\*EPSMCH

[Parallel(n\_jobs=1)]: Done 1 out of 1 | elapsed: 7.3s finished

At iterate 250	f= 1.73653D+05	proj g = 5.99497D+01
At iterate 200	f= 1.73714D+05	proj g = 3.41803D+02
At iterate 300	f= 1.73651D+05	proj g = 4.00901D+01
At iterate 250	f= 1.73706D+05	proj g = 2.28604D+02
At iterate 350	f= 1.73650D+05	proj g = 4.11518D+01
At iterate 300	f= 1.73704D+05	proj g = 5.12114D+01

\* \* \*

Tit = total number of iterations  
Tnf = total number of function evaluations  
Tnint = total number of segments explored during Cauchy searches  
Skip = number of BFGS updates skipped  
Nact = number of active bounds at final generalized Cauchy point  
Projg = norm of the final projected gradient  
F = final function value

\* \* \*

N	Tit	Tnf	Tnint	Skip	Nact	Projg	F
66	379	418	1	0	0	7.428D+00	1.737D+05
F =	173650.26025182026						

CONVERGENCE: REL\_REDUCTION\_OF\_F\_<=\_FACTR\*EPSMCH

[Parallel(n\_jobs=1)]: Done 1 out of 1 | elapsed: 5.8s finished

At iterate 350 f= 1.73703D+05 |proj g|= 1.40113D+02

\* \* \*

Tit = total number of iterations  
Tnf = total number of function evaluations  
Tnint = total number of segments explored during Cauchy searches  
Skip = number of BFGS updates skipped  
Nact = number of active bounds at final generalized Cauchy point  
Projg = norm of the final projected gradient  
F = final function value

\* \* \*

N	Tit	Tnf	Tnint	Skip	Nact	Projg	F
66	364	411	1	0	0	1.939D+01	1.737D+05
F =	173703.35422425106						

CONVERGENCE: REL\_REDUCTION\_OF\_F\_<=\_FACTR\*EPSMCH

[Parallel(n\_jobs=1)]: Done 1 out of 1 | elapsed: 5.1s finished

[Parallel(n\_jobs=1)]: Using backend SequentialBackend with 1 concurrent workers.  
This problem is unconstrained.

RUNNING THE L-BFGS-B CODE

\* \* \*

```

Machine precision = 2.220D-16
N =           66      M =           10

At X0          0 variables are exactly at the bounds

At iterate    0      f=  2.22957D+05      |proj g|=  6.50227D+04
At iterate   50      f=  1.94591D+05      |proj g|=  1.62269D+04
At iterate  100      f=  1.93522D+05      |proj g|=  9.58215D+02
At iterate  150      f=  1.93128D+05      |proj g|=  4.98291D+02
At iterate  200      f=  1.93109D+05      |proj g|=  1.59846D+02
At iterate  250      f=  1.93104D+05      |proj g|=  1.27221D+02
At iterate  300      f=  1.93103D+05      |proj g|=  2.15532D+01

* * *

Tit  = total number of iterations
Tnf  = total number of function evaluations
Tnint = total number of segments explored during Cauchy searches
Skip  = number of BFGS updates skipped
Nact  = number of active bounds at final generalized Cauchy point
Projg = norm of the final projected gradient
F     = final function value
Best Parameters: {'C': 0.01}
Best Cross-Validation Score: 0.6452716219637357

[Parallel(n_jobs=1)]: Done    1 out of    1 | elapsed:    7.2s finished

```

\* \* \*

N	Tit	Tnf	Tnint	Skip	Nact	Projg	F
66	315	359	1	0	0	8.758D+00	1.931D+05
F =	193102.97688961128						

CONVERGENCE: REL\_REDUCTION\_OF\_F\_<=\_FACTR\*EPSMCH

```
[32]: # Apply SMOTE
smote = SMOTE(random_state=42)

X_dev_smote, y_dev_smote = smote.fit_resample(X_dev_scaled, y_dev)
```

```
[33]: mlg_smote = LogisticRegression(penalty='l2', C=0.01, multi_class='multinomial',
                                     solver='lbfgs', max_iter=max_iter, random_state=42, verbose=1)
scores_smote = cross_val_score(mlg_smote, X_dev_smote, y_dev_smote, cv=10, error_score="raise")
print("Cross-validation scores:", scores_smote)
print("Mean cross-validation score:", np.mean(scores_smote))
```

[Parallel(n\_jobs=1)]: Using backend SequentialBackend with 1 concurrent workers.  
This problem is unconstrained.

RUNNING THE L-BFGS-B CODE

\* \* \*

Machine precision = 2.220D-16

N = 66 M = 10

At X0 0 variables are exactly at the bounds

At iterate 0 f= 5.07116D+05 |proj g|= 1.49413D+05

At iterate 50 f= 4.37936D+05 |proj g|= 1.24333D+04

At iterate 100 f= 4.34627D+05 |proj g|= 6.26134D+03

At iterate 150 f= 4.33536D+05 |proj g|= 5.16750D+03

At iterate 200 f= 4.33298D+05 |proj g|= 3.18664D+02

At iterate 250 f= 4.33270D+05 |proj g|= 1.23794D+03

At iterate 300 f= 4.33246D+05 |proj g|= 1.02222D+03

At iterate 350 f= 4.33240D+05 |proj g|= 1.56310D+02

At iterate 400 f= 4.33240D+05 |proj g|= 3.95840D+01

[Parallel(n\_jobs=1)]: Done 1 out of 1 | elapsed: 20.5s finished

[Parallel(n\_jobs=1)]: Using backend SequentialBackend with 1 concurrent workers.

\* \* \*

Tit = total number of iterations

Tnf = total number of function evaluations

Tnint = total number of segments explored during Cauchy searches

Skip = number of BFGS updates skipped

Nact = number of active bounds at final generalized Cauchy point

Projg = norm of the final projected gradient  
F = final function value

\* \* \*

N	Tit	Tnf	Tnint	Skip	Nact	Projg	F
66	421	469	1	0	0	5.820D+01	4.332D+05
F =	433239.88380798290						

CONVERGENCE: REL\_REDUCTION\_OF\_F\_<=\_FACTR\*EPSMCH  
RUNNING THE L-BFGS-B CODE

\* \* \*

Machine precision = 2.220D-16

N = 66 M = 10

At X0 0 variables are exactly at the bounds

At iterate 0 f= 5.07116D+05 |proj g|= 1.49335D+05

This problem is unconstrained.

At iterate 50 f= 4.38456D+05 |proj g|= 1.87719D+04

At iterate 100 f= 4.34899D+05 |proj g|= 5.37656D+03

At iterate 150 f= 4.33791D+05 |proj g|= 2.95282D+03

At iterate 200 f= 4.33591D+05 |proj g|= 6.85688D+02

At iterate 250 f= 4.33560D+05 |proj g|= 5.07382D+02

At iterate 300 f= 4.33537D+05 |proj g|= 1.60505D+02

At iterate 350 f= 4.33535D+05 |proj g|= 2.41284D+02

At iterate 400 f= 4.33534D+05 |proj g|= 8.60114D+01

At iterate 450 f= 4.33534D+05 |proj g|= 5.69946D+01

[Parallel(n\_jobs=1)]: Done 1 out of 1 | elapsed: 25.4s finished

[Parallel(n\_jobs=1)]: Using backend SequentialBackend with 1 concurrent workers.

\* \* \*

Tit = total number of iterations

Tnf = total number of function evaluations

Tnint = total number of segments explored during Cauchy searches  
 Skip = number of BFGS updates skipped  
 Nact = number of active bounds at final generalized Cauchy point  
 Projg = norm of the final projected gradient  
 F = final function value

\* \* \*

N	Tit	Tnf	Tnint	Skip	Nact	Projg	F
66	474	529	1	0	0	2.521D+01	4.335D+05
F = 433533.74401708320							

CONVERGENCE: REL\_REDUCTION\_OF\_F\_<=\_FACTR\*EPSMCH  
 RUNNING THE L-BFGS-B CODE

\* \* \*

Machine precision = 2.220D-16

N = 66 M = 10

At X0 0 variables are exactly at the bounds

At iterate 0 f= 5.07116D+05 |proj g|= 1.49635D+05

This problem is unconstrained.

At iterate 50 f= 4.38116D+05 |proj g|= 4.25274D+03

At iterate 100 f= 4.34869D+05 |proj g|= 1.50884D+04

At iterate 150 f= 4.34050D+05 |proj g|= 1.33263D+03

At iterate 200 f= 4.33944D+05 |proj g|= 1.09103D+03

At iterate 250 f= 4.33905D+05 |proj g|= 4.09851D+02

At iterate 300 f= 4.33887D+05 |proj g|= 4.50285D+02

At iterate 350 f= 4.33884D+05 |proj g|= 9.23283D+01

At iterate 400 f= 4.33884D+05 |proj g|= 1.05465D+02

[Parallel(n\_jobs=1)]: Done 1 out of 1 | elapsed: 21.1s finished

[Parallel(n\_jobs=1)]: Using backend SequentialBackend with 1 concurrent workers.

\* \* \*

Tit = total number of iterations

Tnf = total number of function evaluations  
 Tnint = total number of segments explored during Cauchy searches  
 Skip = number of BFGS updates skipped  
 Nact = number of active bounds at final generalized Cauchy point  
 Projg = norm of the final projected gradient  
 F = final function value

\* \* \*

N	Tit	Tnf	Tnint	Skip	Nact	Projg	F
66	406	461	1	0	0	1.089D+02	4.339D+05
F =	433883.89485519438						

CONVERGENCE: REL\_REDUCTION\_OF\_F\_<=FACTR\*EPSMCH

This problem is unconstrained.

RUNNING THE L-BFGS-B CODE

\* \* \*

Machine precision = 2.220D-16

N = 66 M = 10

At X0 0 variables are exactly at the bounds

At iterate 0 f= 5.07116D+05 |proj g|= 1.49710D+05

At iterate 50 f= 4.37549D+05 |proj g|= 1.96181D+04

At iterate 100 f= 4.34632D+05 |proj g|= 7.81808D+03

At iterate 150 f= 4.33903D+05 |proj g|= 2.58105D+03

At iterate 200 f= 4.33733D+05 |proj g|= 4.74493D+02

At iterate 250 f= 4.33708D+05 |proj g|= 5.44877D+02

At iterate 300 f= 4.33687D+05 |proj g|= 4.61410D+02

At iterate 350 f= 4.33684D+05 |proj g|= 7.64203D+01

\* \* \*

Tit = total number of iterations

Tnf = total number of function evaluations

Tnint = total number of segments explored during Cauchy searches

Skip = number of BFGS updates skipped

Nact = number of active bounds at final generalized Cauchy point

```
Projg = norm of the final projected gradient
F      = final function value
```

```
* * *
```

N	Tit	Tnf	Tnint	Skip	Nact	Projg	F
66	394	451	1	0	0	3.253D+01	4.337D+05
F =	433683.54594228847						

```
CONVERGENCE: REL_REDUCTION_OF_F_<=_FACTR*EPSMCH
```

```
[Parallel(n_jobs=1)]: Done 1 out of 1 | elapsed: 28.9s finished
[Parallel(n_jobs=1)]: Using backend SequentialBackend with 1 concurrent workers.
This problem is unconstrained.
```

```
RUNNING THE L-BFGS-B CODE
```

```
* * *
```

```
Machine precision = 2.220D-16
```

```
N = 66 M = 10
```

```
At X0 0 variables are exactly at the bounds
```

```
At iterate 0 f= 5.07116D+05 |proj g|= 1.48982D+05
```

```
At iterate 50 f= 4.38681D+05 |proj g|= 2.11480D+04
```

```
At iterate 100 f= 4.35533D+05 |proj g|= 6.06229D+03
```

```
At iterate 150 f= 4.34038D+05 |proj g|= 1.93415D+03
```

```
At iterate 200 f= 4.33856D+05 |proj g|= 8.00014D+02
```

```
At iterate 250 f= 4.33832D+05 |proj g|= 4.09784D+02
```

```
At iterate 300 f= 4.33811D+05 |proj g|= 6.41148D+02
```

```
At iterate 350 f= 4.33807D+05 |proj g|= 1.44260D+02
```

```
[Parallel(n_jobs=1)]: Done 1 out of 1 | elapsed: 21.2s finished
```

```
[Parallel(n_jobs=1)]: Using backend SequentialBackend with 1 concurrent workers.
This problem is unconstrained.
```

```
* * *
```

```
Tit = total number of iterations
```

```
Tnf = total number of function evaluations
```

```
Tnint = total number of segments explored during Cauchy searches
```

Skip = number of BFGS updates skipped  
 Nact = number of active bounds at final generalized Cauchy point  
 Projg = norm of the final projected gradient  
 F = final function value

\* \* \*

N	Tit	Tnf	Tnint	Skip	Nact	Projg	F
66	389	436	1	0	0	2.926D+01	4.338D+05
F =	433806.79620617849						

CONVERGENCE: REL\_REDUCTION\_OF\_F\_<=\_FACTR\*EPSMCH  
 RUNNING THE L-BFGS-B CODE

\* \* \*

Machine precision = 2.220D-16

N = 66 M = 10

At X0 0 variables are exactly at the bounds

At iterate 0 f= 5.07116D+05 |proj g|= 1.49813D+05

At iterate 50 f= 4.38502D+05 |proj g|= 2.03542D+04

At iterate 100 f= 4.35216D+05 |proj g|= 1.39749D+04

At iterate 150 f= 4.34019D+05 |proj g|= 1.35749D+03

At iterate 200 f= 4.33848D+05 |proj g|= 1.00833D+03

At iterate 250 f= 4.33824D+05 |proj g|= 5.96135D+02

At iterate 300 f= 4.33802D+05 |proj g|= 9.55240D+02

At iterate 350 f= 4.33797D+05 |proj g|= 2.62519D+01

[Parallel(n\_jobs=1)]: Done 1 out of 1 | elapsed: 22.8s finished

[Parallel(n\_jobs=1)]: Using backend SequentialBackend with 1 concurrent workers.

\* \* \*

Tit = total number of iterations  
 Tnf = total number of function evaluations  
 Tnint = total number of segments explored during Cauchy searches  
 Skip = number of BFGS updates skipped  
 Nact = number of active bounds at final generalized Cauchy point  
 Projg = norm of the final projected gradient

F = final function value

\* \* \*

N	Tit	Tnf	Tnint	Skip	Nact	Projg	F
66	397	440	1	0	0	2.049D+01	4.338D+05
F =	433796.70564200432						

CONVERGENCE: REL\_REDUCTION\_OF\_F\_<=\_FACTR\*EPSMCH

This problem is unconstrained.

RUNNING THE L-BFGS-B CODE

\* \* \*

Machine precision = 2.220D-16

N = 66 M = 10

At X0 0 variables are exactly at the bounds

At iterate 0 f= 5.07117D+05 |proj g|= 1.49856D+05

At iterate 50 f= 4.38587D+05 |proj g|= 7.75750D+03

At iterate 100 f= 4.35174D+05 |proj g|= 3.56765D+03

At iterate 150 f= 4.34027D+05 |proj g|= 1.38396D+04

At iterate 200 f= 4.33838D+05 |proj g|= 1.55940D+03

At iterate 250 f= 4.33801D+05 |proj g|= 3.14777D+02

At iterate 300 f= 4.33786D+05 |proj g|= 9.83268D+02

At iterate 350 f= 4.33783D+05 |proj g|= 4.31510D+02

At iterate 400 f= 4.33782D+05 |proj g|= 1.03041D+02

At iterate 450 f= 4.33782D+05 |proj g|= 4.53283D+01

\* \* \*

Tit = total number of iterations

Tnf = total number of function evaluations

Tnint = total number of segments explored during Cauchy searches

Skip = number of BFGS updates skipped

Nact = number of active bounds at final generalized Cauchy point

Projg = norm of the final projected gradient

F = final function value

\* \* \*

N	Tit	Tnf	Tnint	Skip	Nact	Projg	F
66	451	500	1	0	0	2.244D+01	4.338D+05
F =	433781.84300680138						

CONVERGENCE: REL\_REDUCTION\_OF\_F\_<=\_FACTR\*EPSMCH

[Parallel(n\_jobs=1)]: Done 1 out of 1 | elapsed: 23.4s finished  
[Parallel(n\_jobs=1)]: Using backend SequentialBackend with 1 concurrent workers.  
This problem is unconstrained.

RUNNING THE L-BFGS-B CODE

\* \* \*

Machine precision = 2.220D-16

N = 66 M = 10

At X0 0 variables are exactly at the bounds

At iterate 0 f= 5.07117D+05 |proj g|= 1.49418D+05

At iterate 50 f= 4.38303D+05 |proj g|= 3.32517D+03

At iterate 100 f= 4.35110D+05 |proj g|= 3.70449D+03

At iterate 150 f= 4.34072D+05 |proj g|= 2.96741D+03

At iterate 200 f= 4.33902D+05 |proj g|= 1.34437D+03

At iterate 250 f= 4.33875D+05 |proj g|= 5.00462D+02

At iterate 300 f= 4.33855D+05 |proj g|= 1.49347D+02

At iterate 350 f= 4.33852D+05 |proj g|= 6.33339D+01

[Parallel(n\_jobs=1)]: Done 1 out of 1 | elapsed: 20.9s finished  
[Parallel(n\_jobs=1)]: Using backend SequentialBackend with 1 concurrent workers.

\* \* \*

Tit = total number of iterations

Tnf = total number of function evaluations

Tnint = total number of segments explored during Cauchy searches

Skip = number of BFGS updates skipped

Nact = number of active bounds at final generalized Cauchy point

Projg = norm of the final projected gradient  
F = final function value

\* \* \*

N	Tit	Tnf	Tnint	Skip	Nact	Projg	F
66	394	448	1	0	0	2.402D+01	4.339D+05
F =	433852.05290626781						

CONVERGENCE: REL\_REDUCTION\_OF\_F\_<=\_FACTR\*EPSMCH  
RUNNING THE L-BFGS-B CODE

\* \* \*

Machine precision = 2.220D-16

N = 66 M = 10

At X0 0 variables are exactly at the bounds

At iterate 0 f= 5.07117D+05 |proj g|= 1.48820D+05

This problem is unconstrained.

At iterate 50 f= 4.38651D+05 |proj g|= 1.63930D+04

At iterate 100 f= 4.35521D+05 |proj g|= 2.47065D+04

At iterate 150 f= 4.34102D+05 |proj g|= 3.44385D+03

At iterate 200 f= 4.33869D+05 |proj g|= 3.01702D+03

At iterate 250 f= 4.33832D+05 |proj g|= 1.27972D+03

At iterate 300 f= 4.33813D+05 |proj g|= 6.19943D+02

At iterate 350 f= 4.33807D+05 |proj g|= 1.26641D+02

At iterate 400 f= 4.33805D+05 |proj g|= 1.44537D+02

At iterate 450 f= 4.33805D+05 |proj g|= 8.69842D+01

[Parallel(n\_jobs=1)]: Done 1 out of 1 | elapsed: 26.0s finished

[Parallel(n\_jobs=1)]: Using backend SequentialBackend with 1 concurrent workers.

\* \* \*

Tit = total number of iterations

Tnf = total number of function evaluations

Tnint = total number of segments explored during Cauchy searches  
 Skip = number of BFGS updates skipped  
 Nact = number of active bounds at final generalized Cauchy point  
 Projg = norm of the final projected gradient  
 F = final function value

\* \* \*

N	Tit	Tnf	Tnint	Skip	Nact	Projg	F
66	475	536	1	0	0	4.186D+01	4.338D+05
F = 433804.81686879665							

CONVERGENCE: REL\_REDUCTION\_OF\_F\_<=\_FACTR\*EPSMCH

This problem is unconstrained.

RUNNING THE L-BFGS-B CODE

\* \* \*

Machine precision = 2.220D-16

N = 66 M = 10

At X0 0 variables are exactly at the bounds

At iterate 0 f= 5.07117D+05 |proj g|= 1.49562D+05

At iterate 50 f= 4.38378D+05 |proj g|= 1.07247D+04

At iterate 100 f= 4.35154D+05 |proj g|= 2.79413D+03

At iterate 150 f= 4.34049D+05 |proj g|= 6.27885D+03

At iterate 200 f= 4.33877D+05 |proj g|= 2.31839D+03

At iterate 250 f= 4.33846D+05 |proj g|= 7.12512D+02

At iterate 300 f= 4.33833D+05 |proj g|= 1.78417D+02

At iterate 350 f= 4.33831D+05 |proj g|= 4.03343D+01

\* \* \*

Tit = total number of iterations

Tnf = total number of function evaluations

Tnint = total number of segments explored during Cauchy searches

Skip = number of BFGS updates skipped

Nact = number of active bounds at final generalized Cauchy point

Projg = norm of the final projected gradient

```

F      = final function value

* * *

N      Tit      Tnf      Tnint     Skip     Nact      Projg      F
66      369      417      1        0        0    9.780D+01   4.338D+05
F = 433831.25034125836

CONVERGENCE: REL_REDUCTION_OF_F_<=_FACTR*EPSMCH
Cross-validation scores: [0.52110589 0.52268518 0.53126401 0.52884634 0.53321375
0.53171245
0.52702387 0.52868117 0.52838871 0.5301825 ]
Mean cross-validation score: 0.5283103867812668

[Parallel(n_jobs=1)]: Done    1 out of    1 | elapsed:   17.9s finished

```

```
[34]: rus = RandomUnderSampler(random_state=42)
X_dev_undersampled, y_dev_undersampled = rus.fit_resample(X_dev_scaled, y_dev)
```

```
[35]: mlg_undersampled = LogisticRegression(
    penalty='l2',
    C=0.01,
    multi_class='multinomial',
    solver='lbfgs',
    max_iter=max_iter,
    random_state=42,
    verbose=1
)

scores_undersampled = cross_val_score(mlg_undersampled, X_dev_undersampled, y_dev_undersampled, cv=10, error_score="raise")
print("Cross-validation scores with undersampling:", scores_undersampled)
print("Mean cross-validation score with undersampling:", np.mean(scores_undersampled))
```

```
[Parallel(n_jobs=1)]: Using backend SequentialBackend with 1 concurrent workers.
This problem is unconstrained.
```

RUNNING THE L-BFGS-B CODE

```

* * *

Machine precision = 2.220D-16
N =           66      M =           10

At X0          0 variables are exactly at the bounds

At iterate    0      f=  1.09894D+04      |proj g|=  3.10700D+03
```

```
At iterate 50      f= 9.63907D+03      |proj g|= 4.45793D+02
[Parallel(n_jobs=1)]: Done   1 out of  1 | elapsed:  0.2s finished
[Parallel(n_jobs=1)]: Using backend SequentialBackend with 1 concurrent workers.
```

```
At iterate 100     f= 9.57493D+03      |proj g|= 4.83337D+01
```

```
At iterate 150     f= 9.57265D+03      |proj g|= 1.67828D+00
```

\* \* \*

Tit = total number of iterations  
Tnf = total number of function evaluations  
Tnint = total number of segments explored during Cauchy searches  
Skip = number of BFGS updates skipped  
Nact = number of active bounds at final generalized Cauchy point  
Projg = norm of the final projected gradient  
F = final function value

\* \* \*

N	Tit	Tnf	Tnint	Skip	Nact	Projg	F
66	169	192	1	0	0	1.060D+00	9.573D+03
F =	9572.6410268763011						

```
CONVERGENCE: REL_REDUCTION_OF_F_<= FACTR*EPSMCH
RUNNING THE L-BFGS-B CODE
```

\* \* \*

Machine precision = 2.220D-16

N = 66 M = 10

```
At X0      0 variables are exactly at the bounds
```

```
At iterate 0      f= 1.09894D+04      |proj g|= 3.00533D+03
```

```
At iterate 50     f= 9.64239D+03      |proj g|= 7.00834D+01
```

This problem is unconstrained.

```
At iterate 100    f= 9.58432D+03      |proj g|= 5.52284D+01
```

```
At iterate 150    f= 9.58178D+03      |proj g|= 3.55016D+00
```

\* \* \*

Tit = total number of iterations

Tnf = total number of function evaluations  
 Tnint = total number of segments explored during Cauchy searches  
 Skip = number of BFGS updates skipped  
 Nact = number of active bounds at final generalized Cauchy point  
 Projg = norm of the final projected gradient  
 F = final function value

\* \* \*

N	Tit	Tnf	Tnint	Skip	Nact	Projg	F
66	180	208	1	0	0	5.301D-01	9.582D+03
F =	9581.7626778023332						

CONVERGENCE: REL\_REDUCTION\_OF\_F\_<=\_FACTR\*EPSMCH  
 RUNNING THE L-BFGS-B CODE

\* \* \*

Machine precision = 2.220D-16

N = 66 M = 10

At X0 0 variables are exactly at the bounds

At iterate 0 f= 1.09894D+04 |proj g|= 3.11400D+03

At iterate 50 f= 9.62888D+03 |proj g|= 6.67729D+01

At iterate 100 f= 9.57375D+03 |proj g|= 3.02661D+01

[Parallel(n\_jobs=1)]: Done 1 out of 1 | elapsed: 0.3s finished

[Parallel(n\_jobs=1)]: Using backend SequentialBackend with 1 concurrent workers.

This problem is unconstrained.

[Parallel(n\_jobs=1)]: Done 1 out of 1 | elapsed: 0.2s finished

At iterate 150 f= 9.57258D+03 |proj g|= 4.98330D+00

\* \* \*

Tit = total number of iterations  
 Tnf = total number of function evaluations  
 Tnint = total number of segments explored during Cauchy searches  
 Skip = number of BFGS updates skipped  
 Nact = number of active bounds at final generalized Cauchy point  
 Projg = norm of the final projected gradient  
 F = final function value

\* \* \*

N	Tit	Tnf	Tnint	Skip	Nact	Projg	F
66	172	189	1	0	0	1.661D+00	9.573D+03
F =	9572.5770979264380						

CONVERGENCE: REL\_REDUCTION\_OF\_F\_<=\_FACTR\*EPSMCH  
 RUNNING THE L-BFGS-B CODE

\* \* \*

Machine precision = 2.220D-16

N =	66	M =	10
-----	----	-----	----

At X0 0 variables are exactly at the bounds

At iterate 0 f= 1.09894D+04 |proj g|= 3.11367D+03

At iterate 50 f= 9.64817D+03 |proj g|= 3.97799D+02

At iterate 100 f= 9.58634D+03 |proj g|= 3.62520D+01

[Parallel(n\_jobs=1)]: Using backend SequentialBackend with 1 concurrent workers.  
 This problem is unconstrained.

At iterate 150 f= 9.58474D+03 |proj g|= 3.85916D+00

\* \* \*

Tit = total number of iterations

Tnf = total number of function evaluations

Tnint = total number of segments explored during Cauchy searches

Skip = number of BFGS updates skipped

Nact = number of active bounds at final generalized Cauchy point

Projg = norm of the final projected gradient

F = final function value

\* \* \*

N	Tit	Tnf	Tnint	Skip	Nact	Projg	F
66	182	208	1	0	0	5.835D-01	9.585D+03
F =	9584.7366014659492						

CONVERGENCE: REL\_REDUCTION\_OF\_F\_<=\_FACTR\*EPSMCH  
 RUNNING THE L-BFGS-B CODE

\* \* \*

Machine precision = 2.220D-16

N =	66	M =	10
-----	----	-----	----

```

At X0          0 variables are exactly at the bounds

At iterate    0      f=  1.09894D+04      |proj g|=  3.09033D+03

At iterate    50     f=  9.63358D+03      |proj g|=  3.62850D+02

At iterate   100     f=  9.57718D+03      |proj g|=  1.50255D+02

At iterate   150     f=  9.57516D+03      |proj g|=  3.92471D+00

```

\* \* \*

Tit = total number of iterations  
 Tnf = total number of function evaluations  
 Tnint = total number of segments explored during Cauchy searches  
 Skip = number of BFGS updates skipped  
 Nact = number of active bounds at final generalized Cauchy point  
 Projg = norm of the final projected gradient  
 F = final function value

\* \* \*

N	Tit	Tnf	Tnint	Skip	Nact	Projg	F
66	177	201	1	0	0	7.979D-01	9.575D+03
F = 9575.1435520517662							

CONVERGENCE: REL\_REDUCTION\_OF\_F\_<=\_FACTR\*EPSMCH

[Parallel(n\_jobs=1)]: Done 1 out of 1 | elapsed: 0.2s finished  
 [Parallel(n\_jobs=1)]: Using backend SequentialBackend with 1 concurrent workers.  
 This problem is unconstrained.  
 [Parallel(n\_jobs=1)]: Done 1 out of 1 | elapsed: 0.2s finished  
 [Parallel(n\_jobs=1)]: Using backend SequentialBackend with 1 concurrent workers.  
 This problem is unconstrained.

RUNNING THE L-BFGS-B CODE

\* \* \*

Machine precision = 2.220D-16  
 N = 66 M = 10

At X0 0 variables are exactly at the bounds

```

At iterate    0      f=  1.09905D+04      |proj g|=  3.07500D+03

At iterate    50     f=  9.64194D+03      |proj g|=  3.70171D+02

```

```

At iterate 100      f=  9.57717D+03      |proj g|=  6.48176D+01
At iterate 150      f=  9.57513D+03      |proj g|=  3.86023D+00
[Parallel(n_jobs=1)]: Done   1 out of   1 | elapsed:    0.2s finished
[Parallel(n_jobs=1)]: Using backend SequentialBackend with 1 concurrent workers.
This problem is unconstrained.

```

\* \* \*

```

Tit = total number of iterations
Tnf = total number of function evaluations
Tnint = total number of segments explored during Cauchy searches
Skip = number of BFGS updates skipped
Nact = number of active bounds at final generalized Cauchy point
Projg = norm of the final projected gradient
F = final function value

```

\* \* \*

N	Tit	Tnf	Tnint	Skip	Nact	Projg	F
66	174	190	1	0	0	2.465D+00	9.575D+03
F =	9575.1283378733497						

```

CONVERGENCE: REL_REDUCTION_OF_F_<=_FACTR*EPSMCH
RUNNING THE L-BFGS-B CODE

```

\* \* \*

```

Machine precision = 2.220D-16
N =           66      M =           10

```

At X0 0 variables are exactly at the bounds

At iterate 0 f= 1.09905D+04 |proj g|= 3.06933D+03

At iterate 50 f= 9.63462D+03 |proj g|= 1.65826D+02

At iterate 100 f= 9.57706D+03 |proj g|= 1.55626D+02

At iterate 150 f= 9.57406D+03 |proj g|= 2.28905D+00

\* \* \*

```

Tit = total number of iterations
Tnf = total number of function evaluations
Tnint = total number of segments explored during Cauchy searches
Skip = number of BFGS updates skipped

```

Nact = number of active bounds at final generalized Cauchy point  
 Projg = norm of the final projected gradient  
 F = final function value

\* \* \*

N	Tit	Tnf	Tnint	Skip	Nact	Projg	F
66	183	204	1	0	0	8.288D-01	9.574D+03
F =	9574.0484546830303						

CONVERGENCE: REL\_REDUCTION\_OF\_F\_<=\_FACTR\*EPSMCH  
 RUNNING THE L-BFGS-B CODE

\* \* \*

Machine precision = 2.220D-16

N = 66 M = 10

At X0 0 variables are exactly at the bounds

At iterate 0 f= 1.09905D+04 |proj g|= 3.00133D+03

[Parallel(n\_jobs=1)]: Done 1 out of 1 | elapsed: 0.4s finished  
 [Parallel(n\_jobs=1)]: Using backend SequentialBackend with 1 concurrent workers.  
 This problem is unconstrained.

At iterate 50 f= 9.66214D+03 |proj g|= 1.92366D+02

At iterate 100 f= 9.60488D+03 |proj g|= 1.50981D+02

At iterate 150 f= 9.60327D+03 |proj g|= 2.26143D+00

[Parallel(n\_jobs=1)]: Done 1 out of 1 | elapsed: 0.3s finished  
 [Parallel(n\_jobs=1)]: Using backend SequentialBackend with 1 concurrent workers.  
 This problem is unconstrained.

\* \* \*

Tit = total number of iterations  
 Tnf = total number of function evaluations  
 Tnint = total number of segments explored during Cauchy searches  
 Skip = number of BFGS updates skipped  
 Nact = number of active bounds at final generalized Cauchy point  
 Projg = norm of the final projected gradient  
 F = final function value

\* \* \*

N	Tit	Tnf	Tnint	Skip	Nact	Projg	F
66	175	197	1	0	0	2.083D+00	9.603D+03
F =	9603.2599631107132						

CONVERGENCE: REL\_REDUCTION\_OF\_F\_<=\_FACTR\*EPSMCH  
 RUNNING THE L-BFGS-B CODE

\* \* \*

Machine precision = 2.220D-16

N =	66	M =	10
-----	----	-----	----

At X0 0 variables are exactly at the bounds

At iterate 0 f= 1.09905D+04 |proj g|= 3.07900D+03

At iterate 50 f= 9.63438D+03 |proj g|= 1.02326D+02

At iterate 100 f= 9.57716D+03 |proj g|= 1.89481D+02

At iterate 150 f= 9.57358D+03 |proj g|= 7.40489D+00

\* \* \*

Tit = total number of iterations

Tnf = total number of function evaluations

Tnint = total number of segments explored during Cauchy searches

Skip = number of BFGS updates skipped

Nact = number of active bounds at final generalized Cauchy point

Projg = norm of the final projected gradient

F = final function value

\* \* \*

N	Tit	Tnf	Tnint	Skip	Nact	Projg	F
66	173	195	1	0	0	4.762D-01	9.574D+03
F =	9573.5731365097490						

CONVERGENCE: REL\_REDUCTION\_OF\_F\_<=\_FACTR\*EPSMCH  
 RUNNING THE L-BFGS-B CODE

\* \* \*

Machine precision = 2.220D-16

N =	66	M =	10
-----	----	-----	----

At X0 0 variables are exactly at the bounds

```

At iterate    0      f=  1.09905D+04      |proj g|=  3.11900D+03

At iterate   50      f=  9.61683D+03      |proj g|=  1.67995D+02

At iterate  100      f=  9.55775D+03      |proj g|=  5.26689D+01

[Parallel(n_jobs=1)]: Done   1 out of   1 | elapsed:   0.3s finished
[Parallel(n_jobs=1)]: Using backend SequentialBackend with 1 concurrent workers.
This problem is unconstrained.

At iterate  150      f=  9.55486D+03      |proj g|=  4.32991D+00

* * *

Tit   = total number of iterations
Tnf   = total number of function evaluations
Tnint = total number of segments explored during Cauchy searches
Skip  = number of BFGS updates skipped
Nact  = number of active bounds at final generalized Cauchy point
Projg = norm of the final projected gradient
F     = final function value

* * *

      N   Tit     Tnf   Tnint   Skip   Nact     Projg         F
      66   170     188       1      0      0   4.592D+00   9.555D+03
      F =  9554.8594513222652

CONVERGENCE: REL_REDUCTION_OF_F_<=_FACTR*EPSMCH
Cross-validation scores with undersampling: [0.50719424 0.53147482 0.49010791
0.51258993 0.52338129 0.52205221
0.49594959 0.54005401 0.53105311 0.50045005]
Mean cross-validation score with undersampling: 0.5154307157334439

[Parallel(n_jobs=1)]: Done   1 out of   1 | elapsed:   0.3s finished

```

```
[36]: mlg = LogisticRegression(penalty='l2', C=1.0, multi_class='multinomial',
                               solver='lbfgs', max_iter=max_iter,
                               class_weight='balanced', random_state=42, verbose=1)

mlg.fit(X_dev_scaled, y_dev)

y_dev_pred = mlg.predict(X_dev_scaled)
y_test_pred = mlg.predict(X_test_scaled)

print("Development Set Evaluation:")
print(classification_report(y_dev, y_dev_pred))
print("Accuracy:", accuracy_score(y_dev, y_dev_pred))
```

```

print("\nTest Set Evaluation:")
print(classification_report(y_test, y_test_pred))
print("Accuracy:", accuracy_score(y_test, y_test_pred))

```

RUNNING THE L-BFGS-B CODE

\* \* \*

```

Machine precision = 2.220D-16
N =           66      M =           10

At X0          0 variables are exactly at the bounds

At iterate    0      f=  2.22957D+05      |proj g|=  6.50227D+04
[Parallel(n_jobs=1)]: Using backend SequentialBackend with 1 concurrent workers.
This problem is unconstrained.

At iterate    50      f=  1.94464D+05      |proj g|=  1.20793D+03
At iterate   100      f=  1.93348D+05      |proj g|=  1.86092D+03
At iterate   150      f=  1.93026D+05      |proj g|=  2.05713D+02
At iterate   200      f=  1.93002D+05      |proj g|=  1.05490D+02
At iterate   250      f=  1.92995D+05      |proj g|=  4.41540D+02
At iterate   300      f=  1.92993D+05      |proj g|=  8.14455D+01
[Parallel(n_jobs=1)]: Done    1 out of    1 | elapsed:    7.8s finished


```

\* \* \*

```

Tit = total number of iterations
Tnf = total number of function evaluations
Tnint = total number of segments explored during Cauchy searches
Skip = number of BFGS updates skipped
Nact = number of active bounds at final generalized Cauchy point
Projg = norm of the final projected gradient
F = final function value

```

\* \* \*

N	Tit	Tnf	Tnint	Skip	Nact	Projg	F
66	318	354	1	0	0	4.635D+01	1.930D+05
F =	192992.76567985362						

CONVERGENCE: REL\_REDUCTION\_OF\_F\_<=\_FACTR\*EPSMCH

Development Set Evaluation:

	precision	recall	f1-score	support
0.0	0.95	0.66	0.78	170962
1.0	0.03	0.31	0.06	3705
2.0	0.36	0.59	0.45	28277
accuracy			0.65	202944
macro avg	0.45	0.52	0.43	202944
weighted avg	0.85	0.65	0.72	202944

Accuracy: 0.6455721775465153

Test Set Evaluation:

	precision	recall	f1-score	support
0.0	0.95	0.66	0.78	42741
1.0	0.03	0.33	0.06	926
2.0	0.35	0.58	0.44	7069
accuracy			0.65	50736
macro avg	0.45	0.52	0.43	50736
weighted avg	0.85	0.65	0.72	50736

Accuracy: 0.6458333333333334

```
[37]: feature_names = X_dev_scaled.columns
coefficients = mlg.coef_
coef_df = pd.DataFrame(coefficients.T, index=feature_names, columns=[f'Class_{i}' for i in mlg.classes_])
importance_df = coef_df.abs()
print("Feature importance by class:")
print(importance_df)
```

Feature importance by class:

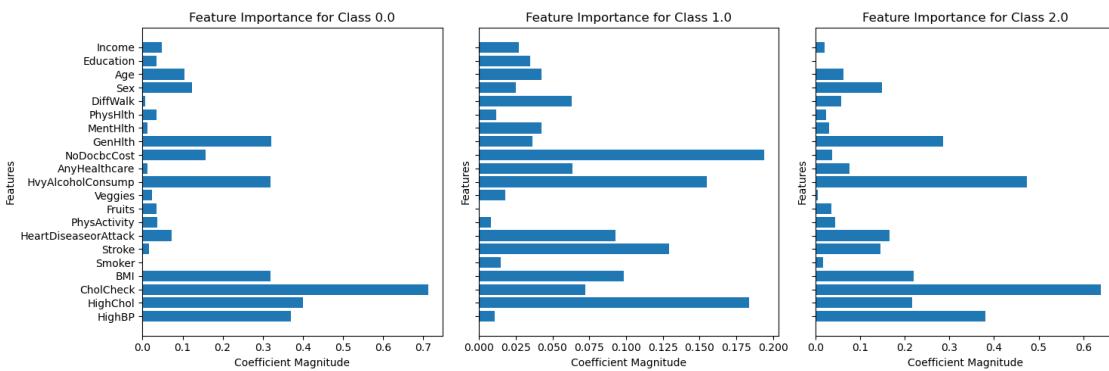
	Class_0.0	Class_1.0	Class_2.0
HighBP	0.370082	0.010581	0.380663
HighChol	0.400497	0.183438	0.217059
CholCheck	0.711958	0.072456	0.639502
BMI	0.318406	0.098336	0.220070
Smoker	0.001653	0.014986	0.016639
Stroke	0.017060	0.129362	0.146422
HeartDiseaseorAttack	0.072772	0.092641	0.165413
PhysActivity	0.036426	0.008291	0.044717
Fruits	0.034730	0.000303	0.035033
Veggies	0.023823	0.018154	0.005669

HvyAlcoholConsump	0.319165	0.154938	0.474103
AnyHealthcare	0.013001	0.063367	0.076368
NoDocbcCost	0.156872	0.194107	0.037235
GenHlth	0.321531	0.036152	0.285379
MentHlth	0.011937	0.042434	0.030497
PhysHlth	0.035057	0.011812	0.023245
DiffWalk	0.005892	0.063174	0.057282
Sex	0.123675	0.024891	0.148566
Age	0.104886	0.042389	0.062496
Education	0.035784	0.034910	0.000874
Income	0.048481	0.027390	0.021090

```
[38]: # Plot feature importance for each class
fig, axes = plt.subplots(nrows=1, ncols=len(mlg.classes_), figsize=(15, 5), sharey=True)

for i, cls in enumerate(mlg.classes_):
    axes[i].barh(importance_df.index, importance_df[f'Class_{cls}'])
    axes[i].set_title(f'Feature Importance for Class {cls}')
    axes[i].set_xlabel('Coefficient Magnitude')
    axes[i].set_ylabel('Features')

plt.tight_layout()
plt.show()
```



**Some results from alternative ML models** Here, we attempt to boost performance on the minority classes (1: prediabetes, 2: diabetes) by training an XGBoost model on the data.

Due to the structure of the dataset, with prediabetes making up just 1.8% of samples and diabetes making up 13.9% of samples, we propose a few different methodologies for improving upon minority class performance.

In just about any class of ML model, the highest accuracy achievable is around ~85%. This is simply due to the fact that models can achieve close to 85% by predicting that everyone is healthy (class=0). The multinomial linear regression model did slightly better than this on minority classes,

but still performed overall pretty poorly on classes 1 and 2.

We propose increasing sample weights of classes 1 and 2 by performing GridSearchCV on the sample\_weight parameter of the XGBoostClassifier model. We see that as we increase the sample\_weight of the minority classes, we notice 2 things: 1) Performance improves in predicting true positives. I.e. the model starts performing better than simply randomly chance on the minority classes. 2) As expected, the cost of improvement in the minority classes is that we have more false positives in the majority classes (below).

We find that you can improve performance in the minority class to an arbitrary degree by increasing the sample\_weight parameter of the minority class. Choosing the correct model in the context depends upon a number of factors. Most notably, the “true cost” of a false positive. In a situation where the true cost of telling someone they may have diabetes is high (health insurance pricing, etc), we would be biased toward a model with fewer false positive, at the cost of worse performance on the diabetes classes. Conversely, in a situation where the true cost of a false positive is lower (for example, flagging to a group of people whether they are at risk without any economic impact to their lives), we would be biased toward a model with more false positives. After all, simply telling someone they are at risk and to eat healthier comes with very little downside in scenarios where our models results have no economic impact to their lives comes with very little downside.

As an example from our work, we see that by increasing the sample\_weight of classes 1 and 2 to just over 1/class\_proportion (in other words, a slightly higher sample weight than if we did “balanced classes”), we can achieve a result of around ~86% true positives on the minority classes, at a cost of only around ~30% false positives on the healthy classes.

Below, we first train a baseline model. Then we perform gridsearch over the sample\_weight parameter and plot our results.

## XGBoost

```
[39]: import time
from xgboost import XGBClassifier
from sklearn.model_selection import GridSearchCV
```

Set a baseline paramgrid so that each xgb model uses the same one

```
[40]: from sklearn.metrics import make_scorer, f1_score, recall_score, precision_score

# param_grid_xgb = {
#     'learning_rate': [0.1, 0.2, 0.3],
#     'max_depth': [2,3,5],
#     'n_estimators': [100, 250, 500]
# }

# param_grid_xgb = {
#     'learning_rate': [0.1, 0.2],
#     'max_depth': [3, 5],
#     'n_estimators': [200, 400]
# }

param_grid_xgb = {
```

```

        'learning_rate': [0.15],
        'max_depth': [4],
        'n_estimators': [300]
    }

scoring_xgb = {
    'accuracy': 'accuracy',
    'f1': make_scorer(f1_score, average='macro', zero_division=0), # Handle undefined cases
    'recall': make_scorer(recall_score, average='macro', zero_division=0),
    'precision': make_scorer(precision_score, average='macro', zero_division=0)
}

xgb_model = XGBClassifier(random_state=42, eval_metric='logloss')

```

### XGB, Balanced Classes, maximize on accuracy

```

[41]: maximize_on = 'accuracy'
scoring = scoring_xgb
param_grid = param_grid_xgb
xgb_model = xgb_model
grid_search = GridSearchCV(estimator=xgb_model,
                           param_grid=param_grid,
                           cv=5,
                           scoring=scoring,
                           refit=maximize_on, # Choose the metric for model selection
                           verbose=1,
                           n_jobs=-1)

# xgb_model_baseline
grid_search.fit(X_dev_scaled, y_dev)
print(f"Best hyperparameters: {grid_search.best_params_}")
print(f"Best cross-validation {maximize_on}: {grid_search.best_score_:.4f}")

# Define and evaluate the model
xgb_model_baseline_accuracy = grid_search.best_estimator_
test_accuracy = xgb_model_baseline_accuracy.score(X_test_scaled, y_test)
print(f"Test accuracy from the optimal model: {test_accuracy:.4f}")
y_pred = xgb_model_baseline_accuracy.predict(X_test_scaled)
print(f"\nClassification Report (Test Data) for xgb_model_baseline_{maximize_on}:")
print(classification_report(y_test, y_pred))

```

Fitting 5 folds for each of 1 candidates, totalling 5 fits  
Best hyperparameters: {'learning\_rate': 0.15, 'max\_depth': 4, 'n\_estimators': 300}  
Best cross-validation accuracy: 0.8498  
Test accuracy from the optimal model: 0.8495

```

Classification Report (Test Data) for xgb_model_baseline_accuracy:
      precision    recall  f1-score   support

        0.0       0.86      0.98      0.92     42741
        1.0       0.00      0.00      0.00      926
        2.0       0.56      0.18      0.28     7069

   accuracy                           0.85      50736
macro avg       0.47      0.39      0.40      50736
weighted avg    0.81      0.85      0.81      50736

```

```

/opt/anaconda3/lib/python3.11/site-
packages/sklearn/metrics/_classification.py:1344: UndefinedMetricWarning:
Precision and F-score are ill-defined and being set to 0.0 in labels with no
predicted samples. Use `zero_division` parameter to control this behavior.
    _warn_prf(average, modifier, msg_start, len(result))
/opt/anaconda3/lib/python3.11/site-
packages/sklearn/metrics/_classification.py:1344: UndefinedMetricWarning:
Precision and F-score are ill-defined and being set to 0.0 in labels with no
predicted samples. Use `zero_division` parameter to control this behavior.
    _warn_prf(average, modifier, msg_start, len(result))
/opt/anaconda3/lib/python3.11/site-
packages/sklearn/metrics/_classification.py:1344: UndefinedMetricWarning:
Precision and F-score are ill-defined and being set to 0.0 in labels with no
predicted samples. Use `zero_division` parameter to control this behavior.
    _warn_prf(average, modifier, msg_start, len(result))

```

### XGB, balanced classes, maximize on f1

```

[42]: maximize_on = 'f1'
scoring = scoring_xgb
param_grid = param_grid_xgb
xgb_model = xgb_model
grid_search = GridSearchCV(estimator=xgb_model,
                           param_grid=param_grid,
                           cv=5,
                           scoring=scoring,
                           refit=maximize_on, # Choose the metric for model
                           ↪selection
                           verbose=1,
                           n_jobs=-1)
# xgb_model_baseline
grid_search.fit(X_dev_scaled, y_dev)
print(f"Best hyperparameters: {grid_search.best_params_}")
print(f"Best cross-validation {maximize_on}: {grid_search.best_score_:.4f}")
# Define and evaluate the model
xgb_model_baseline_f1 = grid_search.best_estimator_
test_accuracy = xgb_model_baseline_f1.score(X_test_scaled, y_test)

```

```

print(f"Test accuracy from the optimal model: {test_accuracy:.4f}")
y_pred = xgb_model_baseline_f1.predict(X_test_scaled)
print(f"\nClassification Report (Test Data) for\u
    ↪xgb_model_baseline_{maximize_on}:")
print(classification_report(y_test, y_pred))

```

Fitting 5 folds for each of 1 candidates, totalling 5 fits  
Best hyperparameters: {'learning\_rate': 0.15, 'max\_depth': 4, 'n\_estimators': 300}  
Best cross-validation f1: 0.4000  
Test accuracy from the optimal model: 0.8495

	precision	recall	f1-score	support
0.0	0.86	0.98	0.92	42741
1.0	0.00	0.00	0.00	926
2.0	0.56	0.18	0.28	7069
accuracy			0.85	50736
macro avg	0.47	0.39	0.40	50736
weighted avg	0.81	0.85	0.81	50736

```

/opt/anaconda3/lib/python3.11/site-
packages/sklearn/metrics/_classification.py:1344: UndefinedMetricWarning:
Precision and F-score are ill-defined and being set to 0.0 in labels with no
predicted samples. Use `zero_division` parameter to control this behavior.
    _warn_prf(average, modifier, msg_start, len(result))
/opt/anaconda3/lib/python3.11/site-
packages/sklearn/metrics/_classification.py:1344: UndefinedMetricWarning:
Precision and F-score are ill-defined and being set to 0.0 in labels with no
predicted samples. Use `zero_division` parameter to control this behavior.
    _warn_prf(average, modifier, msg_start, len(result))
/opt/anaconda3/lib/python3.11/site-
packages/sklearn/metrics/_classification.py:1344: UndefinedMetricWarning:
Precision and F-score are ill-defined and being set to 0.0 in labels with no
predicted samples. Use `zero_division` parameter to control this behavior.
    _warn_prf(average, modifier, msg_start, len(result))

```

### XGB, balanced classes, maximize on recall

```

[43]: maximize_on = 'recall'
scoring = scoring_xgb
param_grid = param_grid_xgb
xgb_model = xgb_model
grid_search = GridSearchCV(estimator=xgb_model,
                           param_grid=param_grid,
                           cv=5,

```

```

        scoring=scoring,
        refit=maximize_on, # Choose the metric for model
    ↵selection

        verbose=1,
        n_jobs=-1)

grid_search.fit(X_dev_scaled, y_dev)
print(f"Best hyperparameters: {grid_search.best_params_}")
print(f"Best cross-validation {maximize_on}: {grid_search.best_score_:.4f}")
# Define and evaluate the model
xgb_model_baseline_recall = grid_search.best_estimator_
test_accuracy = xgb_model_baseline_recall.score(X_test_scaled, y_test)
print(f"Test accuracy from the optimal model: {test_accuracy:.4f}")
y_pred = xgb_model_baseline_recall.predict(X_test_scaled)
print(f"\nClassification Report (Test Data) for"
    ↵xgb_model_baseline_{maximize_on}:")
print(classification_report(y_test, y_pred))

```

Fitting 5 folds for each of 1 candidates, totalling 5 fits  
Best hyperparameters: {'learning\_rate': 0.15, 'max\_depth': 4, 'n\_estimators': 300}  
Best cross-validation recall: 0.3888  
Test accuracy from the optimal model: 0.8495

Classification Report (Test Data) for xgb\_model\_baseline\_recall:

	precision	recall	f1-score	support
0.0	0.86	0.98	0.92	42741
1.0	0.00	0.00	0.00	926
2.0	0.56	0.18	0.28	7069
accuracy			0.85	50736
macro avg	0.47	0.39	0.40	50736
weighted avg	0.81	0.85	0.81	50736

```

/opt/anaconda3/lib/python3.11/site-
packages/sklearn/metrics/_classification.py:1344: UndefinedMetricWarning:
Precision and F-score are ill-defined and being set to 0.0 in labels with no
predicted samples. Use `zero_division` parameter to control this behavior.
    _warn_prf(average, modifier, msg_start, len(result))
/opt/anaconda3/lib/python3.11/site-
packages/sklearn/metrics/_classification.py:1344: UndefinedMetricWarning:
Precision and F-score are ill-defined and being set to 0.0 in labels with no
predicted samples. Use `zero_division` parameter to control this behavior.
    _warn_prf(average, modifier, msg_start, len(result))
/opt/anaconda3/lib/python3.11/site-

```

```
packages/sklearn/metrics/_classification.py:1344: UndefinedMetricWarning:
Precision and F-score are ill-defined and being set to 0.0 in labels with no
predicted samples. Use `zero_division` parameter to control this behavior.
    _warn_prf(average, modifier, msg_start, len(result))
```

We see that when sample\_weight parameter is left as is, as expected performance in classes 1 and 2 is quite poor, with class 1 actually reporting 0 true positives on most of the model iterations. We now explore ways to increase the sample importance of classes 1 and 2, principally by applying a multiplier of 1/class\_proportion to first 1) see how the models would perform when all classes are equally represented (similar to SMOTE above) 2) see how high we would need to increase the sample\_weight parameters of the minority classes to achieve different benchmarks of performance

[44]: # Re-compute class weights for just the dev set to prevent information leakage

```
dev_class_totals = y_dev.value_counts().sort_index()
dev_class_proportions = dev_class_totals/dev_class_totals.sum()
print(f"dev_class_proportions:\n {dev_class_proportions}")
```

```
dev_class_proportions:
Diabetes
0.0    0.842410
1.0    0.018256
2.0    0.139334
Name: count, dtype: float64
```

Set class\_weight equal to the inverse of the class\_proportion of the development set

[45]:

```
dev_class_weights = 1/dev_class_proportions
print(f"dev_class_weights: {dev_class_weights}")
# Create a series corresponding to the weight of each label in y_dev. ~1 for nodiabetes (0), ~7 for diabetes (2), ~54 for prediabetes (1)
sample_weights_dev = y_dev.map(dev_class_weights)
print(sample_weights_dev)
```

```
dev_class_weights: Diabetes
0.0    1.187071
1.0    54.775709
2.0    7.176999
Name: count, dtype: float64
185494    1.187071
217030    1.187071
641      1.187071
217863    1.187071
53677     1.187071
...
230663    1.187071
202400    1.187071
176569    1.187071
248159    1.187071
110153    1.187071
```

```
Name: Diabetes, Length: 202944, dtype: float64
```

We now train a baseline model with `sample_weight` set to `1/class_proportion`, followed by performing a gridsearch on the `sample_weight` parameter below to assess the cost (in the form of false diabetes diagnoses to class 0) of achieving a given benchmark performance on the minority classes.

```
[46]: maximize_on = 'accuracy'  
scoring = scoring_xgb  
param_grid = param_grid_xgb  
xgb_model = xgb_model  
grid_search = GridSearchCV(estimator=xgb_model,  
                           param_grid=param_grid,  
                           cv=5,  
                           scoring=scoring,  
                           refit=maximize_on, # Choose the metric for model  
                           ↪selection  
                           verbose=1,  
                           n_jobs=-1)  
  
# xgb_model_baseline  
grid_search.fit(X_dev_scaled, y_dev, sample_weight=sample_weights_dev) # We  
# ↪increase the weights of classes 1 and 2  
print(f"Best hyperparameters: {grid_search.best_params_}")  
print(f"Best cross-validation {maximize_on}: {grid_search.best_score_.4f}")  
# Define and evaluate the model  
xgb_model_weighted_accuracy = grid_search.best_estimator_  
test_accuracy = xgb_model_weighted_accuracy.score(X_test_scaled, y_test)  
print(f"Test accuracy from the optimal model: {test_accuracy:.4f}")  
y_pred = xgb_model_weighted_accuracy.predict(X_test_scaled)  
print(f"\nClassification Report (Test Data) for  
# ↪xgb_model_weighted_{maximize_on}:")  
print(classification_report(y_test, y_pred))
```

```
Fitting 5 folds for each of 1 candidates, totalling 5 fits  
Best hyperparameters: {'learning_rate': 0.15, 'max_depth': 4, 'n_estimators':  
300}  
Best cross-validation accuracy: 0.6293  
Test accuracy from the optimal model: 0.6302
```

```
Classification Report (Test Data) for xgb_model_weighted_accuracy:  
precision    recall   f1-score   support
```

	precision	recall	f1-score	support
0.0	0.95	0.64	0.77	42741
1.0	0.03	0.31	0.06	926
2.0	0.34	0.62	0.44	7069
accuracy			0.63	50736
macro avg	0.44	0.52	0.42	50736
weighted avg	0.85	0.63	0.71	50736

XGB, sample\_weights now equal to inverse of class proportion, maximize on f1

```
[47]: maximize_on = 'f1'
scoring = scoring_xgb
param_grid = param_grid_xgb
xgb_model = xgb_model
grid_search = GridSearchCV(estimator=xgb_model,
                           param_grid=param_grid,
                           cv=5,
                           scoring=scoring,
                           refit=maximize_on, # Choose the metric for model
                           ↵selection
                           verbose=1,
                           n_jobs=-1)

grid_search.fit(X_dev_scaled, y_dev, sample_weight=sample_weights_dev) # We
                           ↵increase the weights of classes 1 and 2
print(f"Best hyperparameters: {grid_search.best_params_}")
print(f"Best cross-validation {maximize_on}: {grid_search.best_score_.4f}")
# Define and evaluate the model
xgb_model_weighted_f1 = grid_search.best_estimator_
test_accuracy = xgb_model_weighted_f1.score(X_test_scaled, y_test)
print(f"Test accuracy from the optimal model: {test_accuracy:.4f}")
y_pred = xgb_model_weighted_f1.predict(X_test_scaled)
print(f"\nClassification Report (Test Data) for
                           ↵xgb_model_weighted_{maximize_on}:")
print(classification_report(y_test, y_pred))
```

Fitting 5 folds for each of 1 candidates, totalling 5 fits

Best hyperparameters: {'learning\_rate': 0.15, 'max\_depth': 4, 'n\_estimators': 300}

Best cross-validation f1: 0.4197

Test accuracy from the optimal model: 0.6302

Classification Report (Test Data) for xgb\_model\_weighted\_f1:

	precision	recall	f1-score	support
--	-----------	--------	----------	---------

0.0	0.95	0.64	0.77	42741
1.0	0.03	0.31	0.06	926
2.0	0.34	0.62	0.44	7069

accuracy			0.63	50736
macro avg	0.44	0.52	0.42	50736
weighted avg	0.85	0.63	0.71	50736

XGB, sample\_weights now equal to inverse of class proportion, maximize on recall

```
[48]: maximize_on = 'recall'
scoring = scoring_xgb
param_grid = param_grid_xgb
xgb_model = xgb_model
grid_search = GridSearchCV(estimator=xgb_model,
                           param_grid=param_grid,
                           cv=5,
                           scoring=scoring,
                           refit=maximize_on, # Choose the metric for model
                           ↪selection
                           verbose=1,
                           n_jobs=-1)

grid_search.fit(X_dev_scaled, y_dev, sample_weight=sample_weights_dev) # We
                           ↪increase the weights of classes 1 and 2
print(f"Best hyperparameters: {grid_search.best_params_}")
print(f"Best cross-validation {maximize_on}: {grid_search.best_score_.4f}")
# Define and evaluate the model
xgb_model_weighted_recall = grid_search.best_estimator_
test_accuracy = xgb_model_weighted_recall.score(X_test_scaled, y_test)
print(f"Test accuracy from the optimal model: {test_accuracy:.4f}")
y_pred = xgb_model_weighted_recall.predict(X_test_scaled)
print(f"\nClassification Report (Test Data) for"
      ↪xgb_model_weighted_{maximize_on}:")
print(classification_report(y_test, y_pred))
```

Fitting 5 folds for each of 1 candidates, totalling 5 fits  
 Best hyperparameters: {'learning\_rate': 0.15, 'max\_depth': 4, 'n\_estimators': 300}  
 Best cross-validation recall: 0.5176  
 Test accuracy from the optimal model: 0.6302

Classification Report (Test Data) for xgb_model_weighted_recall:				
	precision	recall	f1-score	support
0.0	0.95	0.64	0.77	42741
1.0	0.03	0.31	0.06	926
2.0	0.34	0.62	0.44	7069
accuracy			0.63	50736
macro avg	0.44	0.52	0.42	50736
weighted avg	0.85	0.63	0.71	50736

We see that performance on the minority classes improved when increasing the sample\_weight parameter of the minority classes.

Now, we perform a gridsearch of the sample\_weight parameter. All “shocks” are based relative to the baseline model where sample\_weight is set to 1/class\_proportion (and not the original baseline model where sample\_weight is not touch at all)

```
[49]: print(f"dev_class_weights: {dev_class_weights}")  
shocks = [  
    0.25,  
    0.5,  
    1,  
    2,  
    4,  
    8,  
    16,  
    32,  
    64,  
] # These shocks will be applied multiplicatively to the sample_weights for  
# diabetes and prediabetes over and above the weights used above  
# So far example, if the sample_weights for classes 0,1,2 are [1.19, 54.78, 7.  
# as per above, a shock of 2 will make the sample_weights  
# equal to [1.19, 109.56, 14.36] (classes 1 and 2 shocked only, not class 0)  
# for example  
baseline_model = xgb_model_weighted_f1  
y_pred = baseline_model.predict(X_test_scaled)  
print(f"\nClassification Report (Test Data) for baseline_model:")  
print(classification_report(y_test, y_pred))  
  
shocked_sample_weights = dev_class_weights.copy()  
  
shocked_sample_weights
```

```
dev_class_weights: Diabetes  
0.0      1.187071  
1.0      54.775709  
2.0      7.176999  
Name: count, dtype: float64
```

```
Classification Report (Test Data) for baseline_model:  
          precision    recall  f1-score   support  
  
          0.0      0.95      0.64      0.77     42741  
          1.0      0.03      0.31      0.06      926  
          2.0      0.34      0.62      0.44     7069  
  
    accuracy                           0.63     50736  
   macro avg       0.44      0.52      0.42     50736  
weighted avg       0.85      0.63      0.71     50736
```

```
[49]: Diabetes
0.0      1.187071
1.0      54.775709
2.0      7.176999
Name: count, dtype: float64
```

Define a diabetes false positive function. This is the conditional probability someone is diagnosed with diabetes or prediabetes, given that they actually have neither. We combine classes 1 and 2 in this analysis for simplicity to capture the bigger picture costs of increasing minority class sample\_weights

```
[50]: # Given you dont have diabetes, the likelihood you get a false diagnosis
```

```
def false_pos_diabetes_rate(y_true,y_pred):
    y_df = pd.DataFrame({'y_true':y_true,'y_pred':y_pred})
    □
    ↵y_df['false_positive']=(y_df['y_true']==0)&((y_df['y_pred']==1)|(y_df['y_pred']==2))
    false_pos = y_df['false_positive'].sum()
    no_diabetes = (y_df['y_true']==0).sum()
    return false_pos/no_diabetes
```

Define a diabetes true positive function. This is the probability that someone with either prediabetes or diabetes is diagnosed with either diabetes or prediabetes.

```
[51]: # Given you are pre or actual diabetes, the likelihood you are diagnosed as such
```

```
def true_pos_diabetes_rate(y_true,y_pred):
    y_df = pd.DataFrame({'y_true':y_true,'y_pred':y_pred})
    □
    ↵y_df['true_positive']=((y_df['y_true']==1)|(y_df['y_true']==2))&((y_df['y_pred']==1)|(y_df['y_pred']==2))
    true_pos = y_df['true_positive'].sum()
    diabetes = ((y_df['y_true']==1)|(y_df['y_true']==2)).sum()
    return true_pos/diabetes
```

```
[52]: shock_results_classification_reports = {}
shock_results_false_positives = {}
shock_results_true_positives = {}

for shock in shocks:
    shocked_sample_weights = dev_class_weights.copy()
    shocked_sample_weights[1] = dev_class_weights[1] * shock
    shocked_sample_weights[2] = dev_class_weights[2] * shock
    shocked_sample_weights_dev = y_dev.map(shocked_sample_weights)
    print(f"shocked_sample_weights: {shocked_sample_weights}")
    maximize_on = 'f1'
    scoring = scoring_xgb
    param_grid = param_grid_xgb
    xgb_model = xgb_model
```

```

grid_search = GridSearchCV(estimator=xgb_model,
                           param_grid=param_grid,
                           cv=5,
                           scoring=scoring,
                           refit=maximize_on,
                           verbose=1,
                           n_jobs=-1)
grid_search.fit(X_dev_scaled, y_dev, □
↳sample_weight=shocked_sample_weights_dev) # Here we adjust the sample□
↳weights to equal the shocked weights
xgb_model_shocked_f1 = grid_search.best_estimator_
y_pred = xgb_model_shocked_f1.predict(X_test_scaled)
print(f"\nClassification Report (Test Data) for shocked model for shock:□
↳{shock}:\n")
print(classification_report(y_test, y_pred))
false_pos_rate = false_pos_diabetes_rate(y_test,y_pred)
print(f"false_positive_rate: {false_pos_rate}")
shock_results_false_positives[shock] = false_pos_rate
true_pos_rate = true_pos_diabetes_rate(y_test,y_pred)
print(f"true_positive_rate: {true_pos_rate}")
shock_results_true_positives[shock] = true_pos_rate
shock_results_classification_reports[shock] = classification_report(y_test, □
↳y_pred)

```

shocked\_sample\_weights: Diabetes  
0.0 1.187071  
1.0 13.693927  
2.0 1.794250  
Name: count, dtype: float64  
Fitting 5 folds for each of 1 candidates, totalling 5 fits

Classification Report (Test Data) for shocked model for shock: 0.25:

	precision	recall	f1-score	support
0.0	0.88	0.94	0.91	42741
1.0	0.06	0.04	0.05	926
2.0	0.49	0.32	0.38	7069
accuracy			0.84	50736
macro avg	0.48	0.43	0.45	50736
weighted avg	0.81	0.84	0.82	50736

false\_positive\_rate: 0.06003603097728177  
true\_positive\_rate: 0.3387116948092558  
shocked\_sample\_weights: Diabetes

```
0.0      1.187071
1.0      27.387854
2.0      3.588499
Name: count, dtype: float64
Fitting 5 folds for each of 1 candidates, totalling 5 fits
```

Classification Report (Test Data) for shocked model for shock: 0.5:

	precision	recall	f1-score	support
0.0	0.92	0.82	0.87	42741
1.0	0.04	0.14	0.06	926
2.0	0.40	0.52	0.45	7069
accuracy			0.77	50736
macro avg	0.45	0.50	0.46	50736
weighted avg	0.83	0.77	0.80	50736

```
false_positive_rate: 0.17725369083549752
true_positive_rate: 0.626266416510319
shocked_sample_weights: Diabetes
0.0      1.187071
1.0      54.775709
2.0      7.176999
Name: count, dtype: float64
Fitting 5 folds for each of 1 candidates, totalling 5 fits
```

Classification Report (Test Data) for shocked model for shock: 1:

	precision	recall	f1-score	support
0.0	0.95	0.64	0.77	42741
1.0	0.03	0.31	0.06	926
2.0	0.34	0.62	0.44	7069
accuracy			0.63	50736
macro avg	0.44	0.52	0.42	50736
weighted avg	0.85	0.63	0.71	50736

```
false_positive_rate: 0.36103507171100346
true_positive_rate: 0.8373983739837398
shocked_sample_weights: Diabetes
0.0      1.187071
1.0      109.551417
2.0      14.353998
Name: count, dtype: float64
Fitting 5 folds for each of 1 candidates, totalling 5 fits
```

Classification Report (Test Data) for shocked model for shock: 2:

	precision	recall	f1-score	support
0.0	0.98	0.45	0.62	42741
1.0	0.02	0.41	0.04	926
2.0	0.31	0.65	0.42	7069
accuracy			0.48	50736
macro avg	0.44	0.50	0.36	50736
weighted avg	0.87	0.48	0.58	50736

false\_positive\_rate: 0.5482791698837182

true\_positive\_rate: 0.9390869293308318

shocked\_sample\_weights: Diabetes

0.0 1.187071

1.0 219.102834

2.0 28.707996

Name: count, dtype: float64

Fitting 5 folds for each of 1 candidates, totalling 5 fits

Classification Report (Test Data) for shocked model for shock: 4:

	precision	recall	f1-score	support
0.0	0.98	0.31	0.47	42741
1.0	0.02	0.45	0.04	926
2.0	0.30	0.66	0.41	7069
accuracy			0.36	50736
macro avg	0.43	0.47	0.31	50736
weighted avg	0.87	0.36	0.45	50736

false\_positive\_rate: 0.693268758335088

true\_positive\_rate: 0.974108818011257

shocked\_sample\_weights: Diabetes

0.0 1.187071

1.0 438.205668

2.0 57.415992

Name: count, dtype: float64

Fitting 5 folds for each of 1 candidates, totalling 5 fits

Classification Report (Test Data) for shocked model for shock: 8:

	precision	recall	f1-score	support
0.0	0.99	0.20	0.34	42741
1.0	0.02	0.48	0.03	926

2.0	0.29	0.66	0.40	7069
accuracy			0.27	50736
macro avg	0.43	0.45	0.26	50736
weighted avg	0.87	0.27	0.34	50736

false\_positive\_rate: 0.7971502772513511  
true\_positive\_rate: 0.9881175734834271  
shocked\_sample\_weights: Diabetes  
0.0 1.187071  
1.0 876.411336  
2.0 114.831984  
Name: count, dtype: float64  
Fitting 5 folds for each of 1 candidates, totalling 5 fits

Classification Report (Test Data) for shocked model for shock: 16:

	precision	recall	f1-score	support
0.0	0.99	0.13	0.23	42741
1.0	0.02	0.49	0.03	926
2.0	0.28	0.66	0.40	7069
accuracy			0.21	50736
macro avg	0.43	0.43	0.22	50736
weighted avg	0.87	0.21	0.25	50736

false\_positive\_rate: 0.8724175849886526  
true\_positive\_rate: 0.9943714821763602  
shocked\_sample\_weights: Diabetes  
0.0 1.187071  
1.0 1752.822672  
2.0 229.663967  
Name: count, dtype: float64  
Fitting 5 folds for each of 1 candidates, totalling 5 fits

Classification Report (Test Data) for shocked model for shock: 32:

	precision	recall	f1-score	support
0.0	0.99	0.08	0.15	42741
1.0	0.01	0.48	0.03	926
2.0	0.27	0.67	0.39	7069
accuracy			0.17	50736
macro avg	0.43	0.41	0.19	50736
weighted avg	0.87	0.17	0.18	50736

```
false_positive_rate: 0.9216911162583936
true_positive_rate: 0.9968730456535334
shocked_sample_weights: Diabetes
0.0      1.187071
1.0      3505.645344
2.0      459.327934
Name: count, dtype: float64
Fitting 5 folds for each of 1 candidates, totalling 5 fits
```

Classification Report (Test Data) for shocked model for shock: 64:

	precision	recall	f1-score	support
0.0	0.99	0.05	0.09	42741
1.0	0.01	0.50	0.03	926
2.0	0.27	0.67	0.38	7069
accuracy			0.14	50736
macro avg	0.43	0.40	0.17	50736
weighted avg	0.87	0.14	0.13	50736

```
false_positive_rate: 0.9521536697784329
true_positive_rate: 0.9976235146966854
```

[53]: `shock_results_false_positives`

```
[53]: {0.25: 0.06003603097728177,
 0.5: 0.17725369083549752,
 1: 0.36103507171100346,
 2: 0.5482791698837182,
 4: 0.693268758335088,
 8: 0.7971502772513511,
 16: 0.8724175849886526,
 32: 0.9216911162583936,
 64: 0.9521536697784329}
```

[54]: `shock_results_true_positives`

```
[54]: {0.25: 0.3387116948092558,
 0.5: 0.626266416510319,
 1: 0.8373983739837398,
 2: 0.9390869293308318,
 4: 0.974108818011257,
 8: 0.9881175734834271,
 16: 0.9943714821763602,
 32: 0.9968730456535334,
 64: 0.9976235146966854}
```

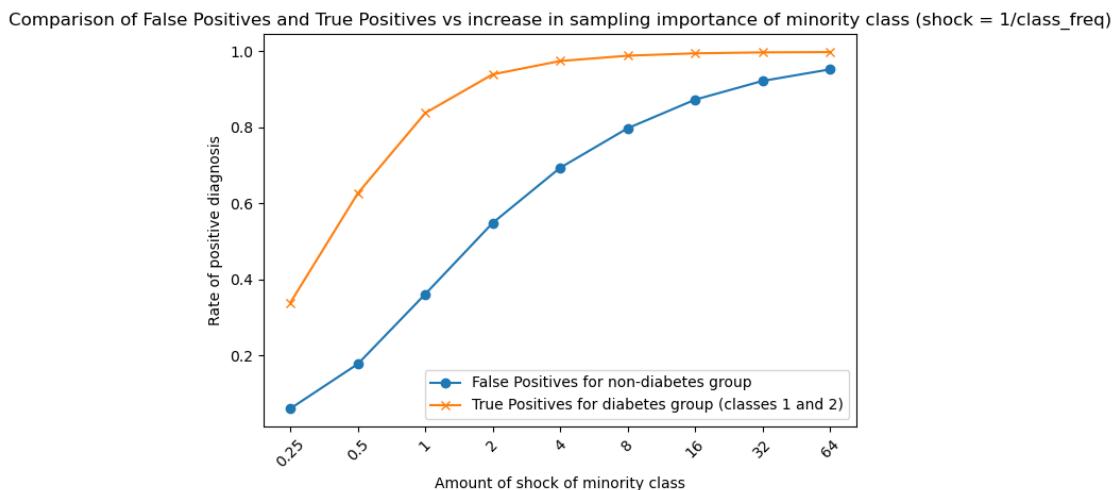
```
[55]: keys = list(shock_results_false_positives.keys())
keys_rounded = [round(k,2) for k in keys]
false_positives = list(shock_results_false_positives.values())
true_positives = list(shock_results_true_positives.values())

x_indices = range(len(keys_rounded))

# Plotting
plt.plot(x_indices, false_positives, label='False Positives for non-diabetes group', marker='o')
plt.plot(x_indices, true_positives, label='True Positives for diabetes group (classes 1 and 2)', marker='x')

# Customize the plot
plt.xticks(x_indices, keys_rounded, rotation=45) # Set the x-ticks to the keys, rotate them for clarity
plt.xlabel('Amount of shock of minority class')
plt.ylabel('Rate of positive diagnosis')
plt.title('Comparison of False Positives and True Positives vs increase in sampling importance of minority class (shock = 1/class_freq)')
plt.legend()

# Show the plot
plt.tight_layout() # To ensure the labels fit
plt.show()
```



Scale sample\_weights exponentially. Examine true positive vs false positive rates.

```
[56]: # Generate numbers from 0 to 2 with a step of 0.2
exp_values = np.arange(0, 2.2, 0.2)
```

```

shock_results_classification_reports_exp = {}
shock_results_false_positives_exp = {}
shock_results_true_positives_exp = {}

for exp_shock in exp_values:
    shocked_sample_weights_exp = dev_class_weights.copy()
    shocked_sample_weights_exp[0] = dev_class_weights[0] ** exp_shock
    shocked_sample_weights_exp[1] = dev_class_weights[1] ** exp_shock
    shocked_sample_weights_exp[2] = dev_class_weights[2] ** exp_shock
    shocked_sample_weights_dev = y_dev.map(shocked_sample_weights_exp)
    print(f"shocked_sample_weights_exp: {shocked_sample_weights_exp}")
    maximize_on = 'f1'
    scoring = scoring_xgb
    param_grid = param_grid_xgb
    xgb_model = xgb_model
    grid_search = GridSearchCV(estimator=xgb_model,
                               param_grid=param_grid,
                               cv=5,
                               scoring=scoring,
                               refit=maximize_on,
                               verbose=1,
                               n_jobs=-1)
    grid_search.fit(X_dev_scaled, y_dev,
                    sample_weight=shocked_sample_weights_dev) # Here we adjust the sample
                    #weights to equal the shocked weights
    xgb_model_shocked_f1 = grid_search.best_estimator_
    y_pred = xgb_model_shocked_f1.predict(X_test_scaled)
    print(f"\nClassification Report (Test Data) for shocked_exp model for"
          f"exp_shock: {exp_shock}:\n")
    print(classification_report(y_test, y_pred))
    false_pos_rate = false_pos_diabetes_rate(y_test, y_pred)
    print(f"false_positive_rate: {false_pos_rate}")
    shock_results_false_positives_exp[exp_shock] = false_pos_rate
    true_pos_rate = true_pos_diabetes_rate(y_test, y_pred)
    print(f"true_positive_rate: {true_pos_rate}")
    shock_results_true_positives_exp[exp_shock] = true_pos_rate
    shock_results_classification_reports_exp[exp_shock] =
        classification_report(y_test, y_pred)

```

```

shocked_sample_weights_exp: Diabetes
0.0      1.0
1.0      1.0
2.0      1.0
Name: count, dtype: float64
Fitting 5 folds for each of 1 candidates, totalling 5 fits

```

Classification Report (Test Data) for shocked\_exp model for exp\_shock: 0.0:

	precision	recall	f1-score	support
0.0	0.86	0.98	0.92	42741
1.0	0.00	0.00	0.00	926
2.0	0.56	0.18	0.28	7069
accuracy			0.85	50736
macro avg	0.47	0.39	0.40	50736
weighted avg	0.81	0.85	0.81	50736

false\_positive\_rate: 0.022063124400458576  
true\_positive\_rate: 0.1742338961851157  
shocked\_sample\_weights\_exp: Diabetes  
0.0 1.034893  
1.0 2.226987  
2.0 1.483162  
Name: count, dtype: float64  
Fitting 5 folds for each of 1 candidates, totalling 5 fits  
  
/opt/anaconda3/lib/python3.11/site-  
packages/sklearn/metrics/\_classification.py:1344: UndefinedMetricWarning:  
Precision and F-score are ill-defined and being set to 0.0 in labels with no  
predicted samples. Use `zero\_division` parameter to control this behavior.  
    \_warn\_prf(average, modifier, msg\_start, len(result))  
  
/opt/anaconda3/lib/python3.11/site-  
packages/sklearn/metrics/\_classification.py:1344: UndefinedMetricWarning:  
Precision and F-score are ill-defined and being set to 0.0 in labels with no  
predicted samples. Use `zero\_division` parameter to control this behavior.  
    \_warn\_prf(average, modifier, msg\_start, len(result))  
  
/opt/anaconda3/lib/python3.11/site-  
packages/sklearn/metrics/\_classification.py:1344: UndefinedMetricWarning:  
Precision and F-score are ill-defined and being set to 0.0 in labels with no  
predicted samples. Use `zero\_division` parameter to control this behavior.  
    \_warn\_prf(average, modifier, msg\_start, len(result))  
  
/opt/anaconda3/lib/python3.11/site-  
packages/sklearn/metrics/\_classification.py:1344: UndefinedMetricWarning:  
Precision and F-score are ill-defined and being set to 0.0 in labels with no  
predicted samples. Use `zero\_division` parameter to control this behavior.  
    \_warn\_prf(average, modifier, msg\_start, len(result))  
  
/opt/anaconda3/lib/python3.11/site-  
packages/sklearn/metrics/\_classification.py:1344: UndefinedMetricWarning:  
Precision and F-score are ill-defined and being set to 0.0 in labels with no  
predicted samples. Use `zero\_division` parameter to control this behavior.  
    \_warn\_prf(average, modifier, msg\_start, len(result))

```
Precision and F-score are ill-defined and being set to 0.0 in labels with no
predicted samples. Use `zero_division` parameter to control this behavior.
```

```
_warn_prf(average, modifier, msg_start, len(result))
```

```
Classification Report (Test Data) for shocked_exp model for exp_shock: 0.2:
```

	precision	recall	f1-score	support
0.0	0.88	0.95	0.91	42741
1.0	0.00	0.00	0.00	926
2.0	0.49	0.31	0.38	7069
accuracy			0.84	50736
macro avg	0.46	0.42	0.43	50736
weighted avg	0.81	0.84	0.82	50736

```
false_positive_rate: 0.04838445520694415
```

```
true_positive_rate: 0.29631019387116947
```

```
shocked_sample_weights_exp: Diabetes
```

```
0.0    1.071003
```

```
1.0    4.959469
```

```
2.0    2.199769
```

```
Name: count, dtype: float64
```

```
Fitting 5 folds for each of 1 candidates, totalling 5 fits
```

```
/opt/anaconda3/lib/python3.11/site-
packages/sklearn/metrics/_classification.py:1344: UndefinedMetricWarning:
Precision and F-score are ill-defined and being set to 0.0 in labels with no
predicted samples. Use `zero_division` parameter to control this behavior.
_warn_prf(average, modifier, msg_start, len(result))
/opt/anaconda3/lib/python3.11/site-
packages/sklearn/metrics/_classification.py:1344: UndefinedMetricWarning:
Precision and F-score are ill-defined and being set to 0.0 in labels with no
predicted samples. Use `zero_division` parameter to control this behavior.
_warn_prf(average, modifier, msg_start, len(result))
/opt/anaconda3/lib/python3.11/site-
packages/sklearn/metrics/_classification.py:1344: UndefinedMetricWarning:
Precision and F-score are ill-defined and being set to 0.0 in labels with no
predicted samples. Use `zero_division` parameter to control this behavior.
_warn_prf(average, modifier, msg_start, len(result))
/opt/anaconda3/lib/python3.11/site-
packages/sklearn/metrics/_classification.py:1344: UndefinedMetricWarning:
Precision and F-score are ill-defined and being set to 0.0 in labels with no
predicted samples. Use `zero_division` parameter to control this behavior.
_warn_prf(average, modifier, msg_start, len(result))
/opt/anaconda3/lib/python3.11/site-
packages/sklearn/metrics/_classification.py:1344: UndefinedMetricWarning:
Precision and F-score are ill-defined and being set to 0.0 in labels with no
predicted samples. Use `zero_division` parameter to control this behavior.
```

```

predicted samples. Use `zero_division` parameter to control this behavior.
    _warn_prf(average, modifier, msg_start, len(result))
/opt/anaconda3/lib/python3.11/site-
packages/sklearn/metrics/_classification.py:1344: UndefinedMetricWarning:
Precision and F-score are ill-defined and being set to 0.0 in labels with no
predicted samples. Use `zero_division` parameter to control this behavior.
    _warn_prf(average, modifier, msg_start, len(result))

```

Classification Report (Test Data) for shocked\_exp model for exp\_shock: 0.4:

	precision	recall	f1-score	support
0.0	0.90	0.91	0.90	42741
1.0	0.00	0.00	0.00	926
2.0	0.44	0.45	0.44	7069
accuracy			0.83	50736
macro avg	0.44	0.45	0.45	50736
weighted avg	0.82	0.83	0.82	50736

```

false_positive_rate: 0.08832268781731827
true_positive_rate: 0.432895559724828
shocked_sample_weights_exp: Diabetes
0.0      1.108373
1.0      11.044671
2.0      3.262614
Name: count, dtype: float64
Fitting 5 folds for each of 1 candidates, totalling 5 fits

```

Classification Report (Test Data) for shocked\_exp model for exp\_shock:  
0.6000000000000001:

	precision	recall	f1-score	support
0.0	0.91	0.85	0.88	42741
1.0	0.01	0.00	0.00	926
2.0	0.39	0.59	0.47	7069
accuracy			0.80	50736
macro avg	0.44	0.48	0.45	50736
weighted avg	0.82	0.80	0.81	50736

```

false_positive_rate: 0.1451299688823378
true_positive_rate: 0.5731081926203877
shocked_sample_weights_exp: Diabetes
0.0      1.147047
1.0      24.596335

```

```
2.0      4.838985
Name: count, dtype: float64
Fitting 5 folds for each of 1 candidates, totalling 5 fits
```

```
Classification Report (Test Data) for shocked_exp model for exp_shock: 0.8:
```

	precision	recall	f1-score	support
0.0	0.93	0.78	0.85	42741
1.0	0.04	0.05	0.04	926
2.0	0.35	0.68	0.46	7069
accuracy			0.76	50736
macro avg	0.44	0.50	0.45	50736
weighted avg	0.83	0.76	0.78	50736

```
false_positive_rate: 0.21705154301490373
true_positive_rate: 0.6933083176985616
shocked_sample_weights_exp: Diabetes
0.0      1.187071
1.0      54.775709
2.0      7.176999
Name: count, dtype: float64
Fitting 5 folds for each of 1 candidates, totalling 5 fits
```

```
Classification Report (Test Data) for shocked_exp model for exp_shock: 1.0:
```

	precision	recall	f1-score	support
0.0	0.95	0.64	0.77	42741
1.0	0.03	0.31	0.06	926
2.0	0.34	0.62	0.44	7069
accuracy			0.63	50736
macro avg	0.44	0.52	0.42	50736
weighted avg	0.85	0.63	0.71	50736

```
false_positive_rate: 0.36103507171100346
true_positive_rate: 0.8373983739837398
shocked_sample_weights_exp: Diabetes
0.0      1.228491
1.0      121.984768
2.0      10.644652
Name: count, dtype: float64
Fitting 5 folds for each of 1 candidates, totalling 5 fits
```

```
Classification Report (Test Data) for shocked_exp model for exp_shock:
1.2000000000000002:
```

	precision	recall	f1-score	support
0.0	0.97	0.45	0.61	42741
1.0	0.02	0.64	0.05	926
2.0	0.38	0.38	0.38	7069
accuracy			0.44	50736
macro avg	0.46	0.49	0.35	50736
weighted avg	0.87	0.44	0.57	50736

```
false_positive_rate: 0.5530755012751223
true_positive_rate: 0.9352095059412132
shocked_sample_weights_exp: Diabetes
0.0      1.271356
1.0      271.658442
2.0      15.787743
Name: count, dtype: float64
Fitting 5 folds for each of 1 candidates, totalling 5 fits
```

Classification Report (Test Data) for shocked\_exp model for exp\_shock:  
1.4000000000000001:

	precision	recall	f1-score	support
0.0	0.98	0.30	0.46	42741
1.0	0.02	0.80	0.04	926
2.0	0.40	0.21	0.27	7069
accuracy			0.29	50736
macro avg	0.47	0.44	0.26	50736
weighted avg	0.88	0.29	0.42	50736

```
false_positive_rate: 0.7031187852413373
true_positive_rate: 0.9743589743589743
shocked_sample_weights_exp: Diabetes
0.0      1.315717
1.0      604.979705
2.0      23.415779
Name: count, dtype: float64
Fitting 5 folds for each of 1 candidates, totalling 5 fits
```

Classification Report (Test Data) for shocked\_exp model for exp\_shock: 1.6:

	precision	recall	f1-score	support
0.0	0.99	0.19	0.32	42741
1.0	0.02	0.90	0.04	926

2.0	0.39	0.12	0.19	7069
accuracy			0.20	50736
macro avg	0.47	0.41	0.18	50736
weighted avg	0.89	0.20	0.30	50736

false\_positive\_rate: 0.8065557661262021  
true\_positive\_rate: 0.9884928080050032  
shocked\_sample\_weights\_exp: Diabetes  
0.0 1.361626  
1.0 1347.281687  
2.0 34.729393  
Name: count, dtype: float64  
Fitting 5 folds for each of 1 candidates, totalling 5 fits

Classification Report (Test Data) for shocked\_exp model for exp\_shock: 1.8:

	precision	recall	f1-score	support
0.0	0.99	0.13	0.23	42741
1.0	0.02	0.93	0.04	926
2.0	0.38	0.09	0.14	7069
accuracy			0.14	50736
macro avg	0.46	0.38	0.14	50736
weighted avg	0.89	0.14	0.21	50736

false\_positive\_rate: 0.8697035633232727  
true\_positive\_rate: 0.9928705440900563  
shocked\_sample\_weights\_exp: Diabetes  
0.0 1.409137  
1.0 3000.378242  
2.0 51.509314  
Name: count, dtype: float64  
Fitting 5 folds for each of 1 candidates, totalling 5 fits

Classification Report (Test Data) for shocked\_exp model for exp\_shock: 2.0:

	precision	recall	f1-score	support
0.0	0.99	0.09	0.16	42741
1.0	0.02	0.94	0.04	926
2.0	0.35	0.07	0.12	7069
accuracy			0.10	50736
macro avg	0.45	0.37	0.11	50736
weighted avg	0.88	0.10	0.15	50736

```
false_positive_rate: 0.9113497578437566
true_positive_rate: 0.9948717948717949
```

```
[57]: shock_results_false_positives_exp
```

```
[57]: {0.0: 0.022063124400458576,
 0.2: 0.04838445520694415,
 0.4: 0.08832268781731827,
 0.6000000000000001: 0.1451299688823378,
 0.8: 0.21705154301490373,
 1.0: 0.36103507171100346,
 1.2000000000000002: 0.5530755012751223,
 1.4000000000000001: 0.7031187852413373,
 1.6: 0.8065557661262021,
 1.8: 0.8697035633232727,
 2.0: 0.9113497578437566}
```

```
[58]: shock_results_true_positives_exp
```

```
[58]: {0.0: 0.1742338961851157,
 0.2: 0.29631019387116947,
 0.4: 0.432895559724828,
 0.6000000000000001: 0.5731081926203877,
 0.8: 0.6933083176985616,
 1.0: 0.8373983739837398,
 1.2000000000000002: 0.9352095059412132,
 1.4000000000000001: 0.9743589743589743,
 1.6: 0.9884928080050032,
 1.8: 0.9928705440900563,
 2.0: 0.9948717948717949}
```

```
[59]: keys = list(shock_results_false_positives_exp.keys())
keys_rounded = [round(k,2) for k in keys]
false_positives = list(shock_results_false_positives_exp.values())
true_positives = list(shock_results_true_positives_exp.values())

x_indices = range(len(keys_rounded))

# Plotting
plt.plot(x_indices, false_positives, label='False Positives for non-diabetes group', marker='o')
plt.plot(x_indices, true_positives, label='True Positives for diabetes group (classes 1 and 2)', marker='x')

# Customize the plot
plt.xticks(x_indices, keys_rounded, rotation=45) # Set the x-ticks to the keys, rotate them for clarity
```

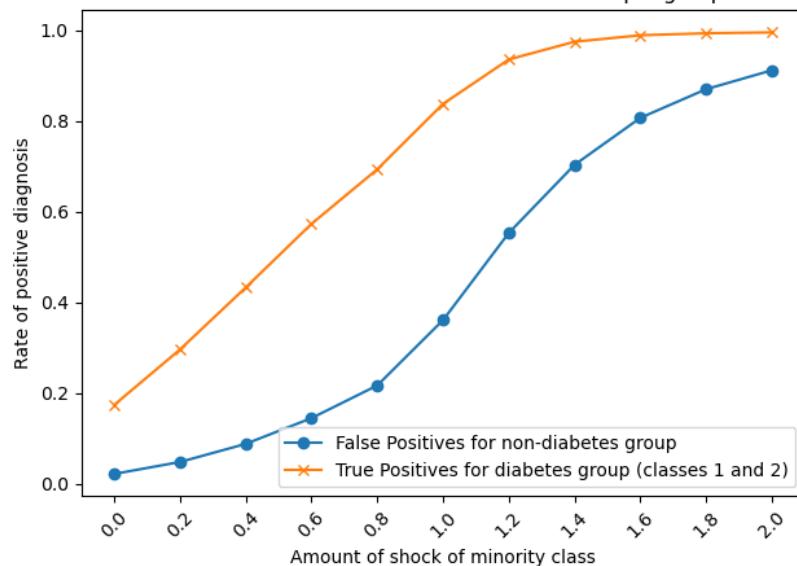
```

plt.xlabel('Amount of shock of minority class')
plt.ylabel('Rate of positive diagnosis')
plt.title('Comparison of False Positives and True Positives vs increase in sampling importance of minority class')
plt.legend()

# Show the plot
plt.tight_layout() # To ensure the labels fit
plt.show()

```

Comparison of False Positives and True Positives vs increase in sampling importance of minority class



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