Task 4 - Modeling & Evaluation

Summary

1. Poor F1 and recall scores due to imbalance classes. Target of interest is churn = 1.
2. Created a model after balancing classes gives better results in these metrics.

Import Libraries

In [1]:
```python
import numpy as np
import pandas as pd
import matplotlib.pyplot as plt
import seaborn as sns
import sklearn
import shap

import xgboost as xgb
from xgboost import XGBClassifier, XGBRegressor
from xgboost import to_graphviz, plot_importance

from yellowbrick.classifier import ClassificationReport, DiscriminationThreshold

#from sklearn.experimental import enable_hist_gradient_boosting
#from sklearn.linear_model import ElasticNet, Lasso, LinearRegression, LogisticRegression, Ridge
from sklearn.ensemble import RandomForestClassifier, RandomForestRegressor, ExtraTreesClassifier, ExtraTrees
#from sklearn.ensemble import GradientBoostingClassifier, GradientBoostingRegressor, HistGradientBoostingCla


%matplotlib inline
sns.set_style('dark')
sns.set(font_scale=1.2)

from sklearn.pipeline import Pipeline
from sklearn.model_selection import RepeatedStratifiedKFold
from sklearn.feature_selection import RFE, RFECV, SelectKBest, f_classif, f_regression, chi2

from sklearn.inspection import permutation_importance
from sklearn.model_selection import cross_val_score, train_test_split, GridSearchCV, RandomizedSearchCV
from sklearn.preprocessing import LabelEncoder, StandardScaler, MinMaxScaler, OneHotEncoder
from sklearn.pipeline import Pipeline
from sklearn.metrics import confusion_matrix, classification_report, mean_absolute_error, mean_squared_error
from sklearn.metrics import plot_confusion_matrix, plot_precision_recall_curve, plot_roc_curve, accuracy_sco
from sklearn.metrics import auc, f1_score, precision_score, recall_score, roc_auc_score


from imblearn.under_sampling import RandomUnderSampler
from imblearn.over_sampling import RandomOverSampler
from imblearn.over_sampling import SMOTE

import warnings
warnings.filterwarnings('ignore')

import pickle
from pickle import dump, load

np.random.seed(0)

from pycaret.classification import *
#from pycaret.clustering import *
#from pycaret.regression import *

pd.set_option('display.max_columns',100)
#pd.set_option('display.max_rows',100)
pd.set_option('display.width', 1000)
np.set_printoptions(suppress=True)
```

Data Exploration and Analysis

In [2]:
```python
df = pd.read_csv("final2.csv")
```

In [3]:
```python
df
```

Out[3]:

	cons_last_month	has_gas	margin_gross_pow_ele	margin_net_pow_ele	nb_prod_act	net_margin	num_years_antig	pow_max	duration
0	10025	0	-41.76	-41.76	1	1732.36	3	180.000	1460.0
1	0	1	25.44	25.44	2	678.99	3	43.648	1096.0
2	0	0	16.38	16.38	1	18.89	6	13.800	2566.0
3	0	0	28.60	28.60	1	6.60	6	13.856	2192.0
4	0	0	30.22	30.22	1	25.46	6	13.200	2192.0
...	...	...	...	...	...	...	...	...	...
16071	0	0	27.88	27.88	2	381.77	4	15.000	1445.0
16072	181	0	0.00	0.00	1	90.34	3	6.000	1461.0
16073	179	0	39.84	39.84	1	20.38	4	15.935	1460.0
16074	0	0	13.08	13.08	1	0.96	3	11.000	1461.0
16075	0	1	11.84	11.84	1	96.34	6	10.392	2556.0

16076 rows × 16 columns

In [4]:
```python
df.info()
```

```
<class 'pandas.core.frame.DataFrame'>
RangeIndex: 16076 entries, 0 to 16075
Data columns (total 16 columns):
 #   Column                Non-Null Count  Dtype
---  ------                --------------  -----
 0   cons_last_month       16076 non-null  int64
 1   has_gas               16076 non-null  int64
 2   margin_gross_pow_ele  16076 non-null  float64
 3   margin_net_pow_ele    16076 non-null  float64
 4   nb_prod_act           16076 non-null  int64
 5   net_margin            16076 non-null  float64
 6   num_years_antig       16076 non-null  int64
 7   pow_max               16076 non-null  float64
 8   duration              16076 non-null  float64
 9   price_p1_var          16076 non-null  float64
 10  price_p2_var          16076 non-null  float64
 11  price_p3_var          16076 non-null  float64
 12  price_p1_fix          16076 non-null  float64
 13  price_p2_fix          16076 non-null  float64
 14  price_p3_fix          16076 non-null  float64
 15  churn                 16076 non-null  int64
dtypes: float64(11), int64(5)
memory usage: 2.0 MB
```

In [5]:
```python
df.describe(include='all')
```

Out[5]:

	cons_last_month	has_gas	margin_gross_pow_ele	margin_net_pow_ele	nb_prod_act	net_margin	num_years_antig	pow_max
count	1.607600e+04	16076.000000	16076.000000	16076.000000	16076.000000	16076.000000	16076.000000	16076.00000
mean	1.943471e+04	0.184188	22.470364	21.467969	1.347972	217.938200	5.029547	20.55486
std	8.233817e+04	0.387649	23.701823	27.920127	1.460638	366.673412	1.675753	21.48370
min	-9.138600e+04	0.000000	-525.540000	-615.660000	1.000000	-4148.990000	1.000000	1.00000
25%	0.000000e+00	0.000000	12.030000	11.950000	1.000000	51.985000	4.000000	12.50000
50%	9.010000e+02	0.000000	21.090000	20.970000	1.000000	119.685000	5.000000	13.85600
75%	4.124000e+03	0.000000	29.640000	29.640000	1.000000	275.772500	6.000000	19.80000
max	4.538720e+06	1.000000	374.640000	374.640000	32.000000	24570.650000	16.000000	500.00000

In [6]:
```python
df.shape
```

Out[6]: (16076, 16)

In [7]:
```python
df.columns
```

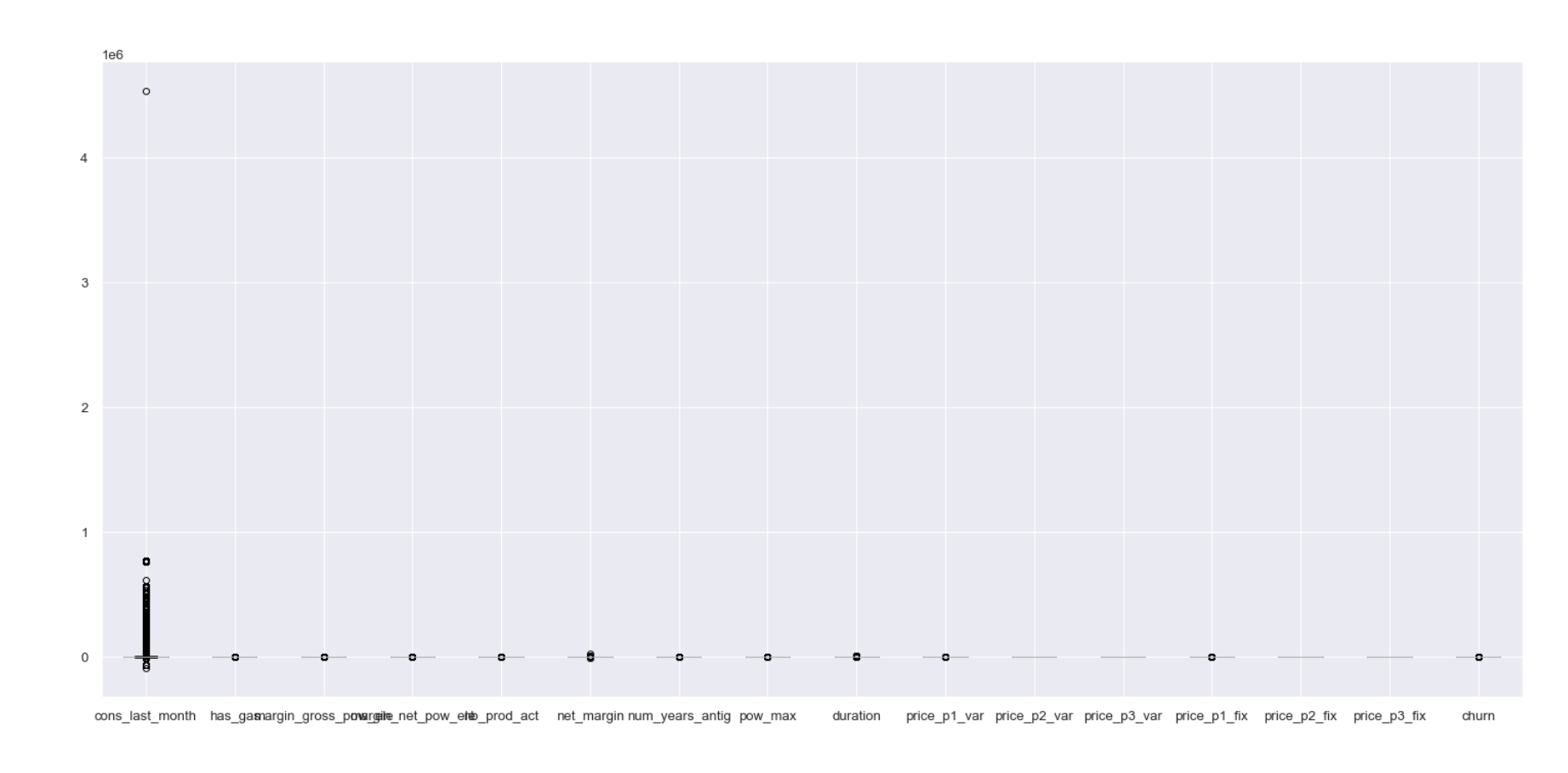
Out[7]:
```
Index(['cons_last_month', 'has_gas', 'margin_gross_pow_ele', 'margin_net_pow_ele', 'nb_prod_act', 'net_margi
n', 'num_years_antig', 'pow_max', 'duration', 'price_p1_var', 'price_p2_var', 'price_p3_var', 'price_p1_fi
x', 'price_p2_fix', 'price_p3_fix', 'churn'], dtype='object')
```

Data Visualization

Univariate Data Exploration

In [8]:
```python
df.hist(bins=50, figsize=(20,15))
plt.suptitle('Feature Distribution', x=0.5, y=1.02, ha='center', fontsize='large')
plt.tight_layout()
plt.show()
```

In [9]:
```python
df.boxplot(figsize=(20,10))
plt.suptitle('BoxPlot', x=0.5, y=1.02, ha='center', fontsize='large')
plt.tight_layout()
plt.show()
```



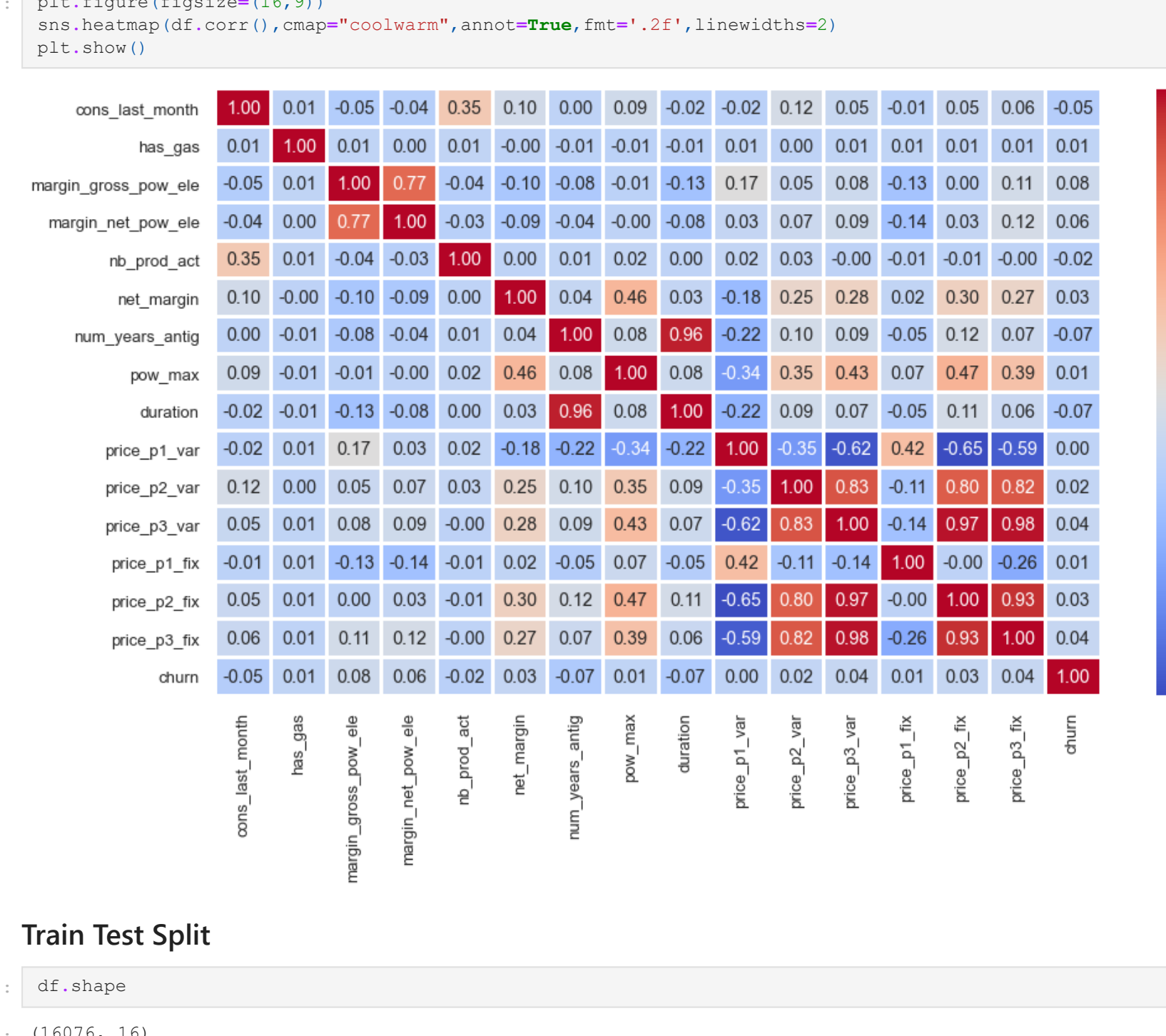
Correlation

In [10]:
```python
df.corr()
```

Out[10]:

	cons_last_month	has_gas	margin_gross_pow_ele	margin_net_pow_ele	nb_prod_act	net_margin	num_years_antig
cons_last_month	1.000000	0.005240	-0.054205	-0.037766	0.351237	0.096491	0.004668
has_gas	0.005240	1.000000	0.009682	0.004285	0.014025	-0.002258	-0.007612
margin_gross_pow_ele	-0.054205	0.009682	1.000000	0.766458	-0.043861	-0.098432	-0.081287
margin_net_pow_ele	-0.037766	0.004285	0.766458	1.000000	-0.032268	-0.086216	-0.037702
nb_prod_act	0.351237	0.014025	-0.043861	-0.032268	1.000000	0.004580	0.009473
net_margin	0.096491	-0.002258	-0.098432	-0.086216	0.004580	1.000000	0.035457
num_years_antig	0.004668	-0.007612	-0.081287	-0.037702	0.009473	0.035457	1.000000
pow_max	0.091558	-0.010297	-0.012871	-0.000556	0.019150	0.457096	0.083967
duration	-0.016011	-0.013632	-0.132225	-0.076409	0.002700	0.026245	0.958616
price_p1_var	-0.017634	0.006187	0.174420	0.031320	0.023988	-0.177704	-0.219561
price_p2_var	0.121125	0.003688	0.054795	0.068608	0.025305	0.253945	0.104251
price_p3_var	0.048831	0.006244	0.075659	0.089121	-0.003503	0.284003	0.085012
price_p1_fix	-0.010839	0.008890	-0.127491	-0.137201	-0.007514	0.015973	-0.050245
price_p2_fix	0.051163	0.005755	0.002869	0.027399	-0.009929	0.300371	0.121350
price_p3_fix	0.056681	0.005278	0.107578	0.115697	-0.000353	0.267859	0.067812
churn	-0.046830	0.007734	0.080280	0.063282	-0.022610	0.029452	-0.072176

In [11]:
```python
plt.figure(figsize=(16,9))
sns.heatmap(df.corr(),cmap="coolwarm",annot=True,fmt='.2f',linewidths=2)
plt.show()
```



Train Test Split

In [23]:
```python
df.shape
```

Out[23]: (16076, 16)

In [24]:
```python
X = df.iloc[:,0:15]
y = df.iloc[:,15]
```

Treat Imbalance Data

In [25]:
```python
y.value_counts()
```

Out[25]:
```
0    14482
1     1594
Name: churn, dtype: int64
```

In [26]:
```python
ros = RandomUnderSampler(sampling_strategy='majority',random_state=0)
```

In [27]:
```python
new_X, new_y = ros.fit_resample(X, y)
```

In [28]:
```python
new_y.value_counts()
```

Out[28]:
```
1    1594
0    1594
Name: churn, dtype: int64
```

In [29]:
```python
new_X
```

Out[29]:

	cons_last_month	has_gas	margin_gross_pow_ele	margin_net_pow_ele	nb_prod_act	net_margin	num_years_antig	pow_max	duration
0	329	0	13.68	13.68	1	17.73	6	11.500	2557.0
1	0	0	21.78	21.78	1	56.33	6	13.200	2557.0
2	365	0	12.30	12.30	1	35.43	6	10.350	2557.0
3	2430	0	2.85	2.85	1	232.65	3	15.100	1461.0
4	243989	0	-3.15	-3.15	2	700.12	5	49.500	1827.0
...	...	...	...	...	...	...	...	...	...
3183	0	0	21.09	21.09	1	36.26	4	10.392	1827.0
3184	0	0	33.12	33.12	1	97.07	3	13.200	1461.0
3185	155	0	7.32	7.32	1	23.29	3	13.856	1481.0
3186	181	0	0.00	0.00	1	90.34	3	6.000	1461.0
3187	179	0	39.84	39.84	1	20.38	4	15.935	1460.0

3188 rows × 15 columns

Train Test Split Cont'd

In [30]:
```python
#X.values, y.values
```

In [31]:
```python
#X_train, X_test, y_train, y_test = train_test_split(X, y, test_size=0.2, random_state=0)
```

In [32]:
```python
#X_train.shape, X_test.shape, y_train.shape, y_test.shape
```

For balanced classes

In [33]:
```python
new_X.values, new_y.values
```

Out[33]:
```
(array([[329.        ,   0.        ,  13.68      , ...,  44.32619046,
           0.        ,   0.        ],
        [  0.        ,   0.        ,  21.78      , ...,  44.40674536,
           0.        ,   0.        ],
        [365.        ,   0.        ,  12.3       , ...,  44.32619046,
           0.        ,   0.        ],
        ...,
        [155.        ,   0.        ,   7.32      , ...,  44.34100546,
           0.        ,   0.        ],
        [181.        ,   0.        ,   0.        , ...,  59.01567351,
          36.3933792 ,   8.34541784],
        [179.        ,   0.        ,  39.84      , ...,  40.7017324 ,
          24.42103848,  16.28069392]]),
 array([0, 0, 0, ..., 1, 1, 1], dtype=int64))
```

In [34]:
```python
X_train, X_test, y_train, y_test = train_test_split(new_X.values, new_y.values, test_size=0.2, random_state=
```

In [35]:
```python
X_train.shape, X_test.shape, y_train.shape, y_test.shape
```

Out[35]: ((2550, 15), (638, 15), (2550,), (638,))

Feature Scaling

In [36]:
```python
X_train
```

Out[36]:
```
array([[  928.        ,     1.        ,    13.26      , ...,
           44.36507876,     0.        ,     0.        ],
       [ 1324.        ,     0.        ,    19.2       , ...,
           44.37063536,     0.        ,     0.        ],
       [    0.        ,     0.        ,    19.2       , ...,
           44.37063516,     0.        ,     0.        ],
       ...,
       [  420.        ,     1.        ,    46.74      , ...,
           40.6474275 ,    24.38845514,    16.25897136],
       [    0.        ,     0.        ,    21.92      , ...,
           44.54655996,     0.        ,     0.        ],
       [13951.        ,     1.        ,    -0.24      , ...,
           40.5659715 ,    24.33957914,    16.22638536]])
```

In [37]:
```python
scaler = StandardScaler()
```

In [38]:
```python
X_train_scaled = scaler.fit_transform(X_train)
```

In [39]:
```python
X_test_scaled = scaler.transform(X_test)
```

In [40]:
```python
X_train_scaled
```

Out[40]:
```
array([[-0.22945191,  2.10919841, -0.38025155, ...,  0.2153079 ,
        -0.87572829, -0.87361503],
       [-0.22340421, -0.47411376, -0.18320252, ...,  0.21658191,
        -0.87572829, -0.87361503],
       [-0.24362428, -0.47411376, -0.18320252, ...,  0.21658187,
        -0.87572829, -0.87361503],
       ...,
       [-0.23721006,  2.10919841,  0.73038844, ..., -0.63707063,
         1.02995854,  1.19687481],
       [-0.24362428, -0.47411376, -0.09297132, ...,  0.25691769,
        -0.87572829, -0.87361503],
       [-0.03056522,  2.10919841, -0.82809026, ..., -0.65574676,
         1.02613942,  1.19272517]])
```

In [41]:
```python
X_test_scaled
```

Out[41]:
```
array([[-0.24362428, -0.47411376,  0.27856895, ...,  0.19280454,
        -0.87572829, -0.87361503],
       [-0.23055149, -0.47411376, -0.04387492, ..., -0.64329601,
         1.0286855 ,  1.1954916 ],
       [-0.24362428, -0.47411376,  0.08019298, ...,  0.22337542,
        -0.87572829, -0.87361503],
       ...,
       [-0.24362428, -0.47411376, -0.22035655, ...,  0.25691778,
        -0.87572829, -0.87361503],
       [ 1.63325331, -0.47411376, -0.61511808, ...,  0.19280456,
        -0.87572829, -0.87361503],
       [-0.2404019 , -0.47411376, -0.10624061, ...,  0.21318512,
        -0.87572829, -0.87361503]])
```

Model Training

Using PyCaret

In [12]:
```python
exp = setup(data = df, target = 'churn', session_id=0, normalize=True, train_size=0.8, fix_imbalance=False)
```

	Description	Value
0	session_id	0
1	Target	churn
2	Target Type	Binary
3	Label Encoded	0: 0, 1: 1
4	Original Data	(16076, 16)
5	Missing Values	False
6	Numeric Features	12
7	Categorical Features	3
8	Ordinal Features	False
9	High Cardinality Features	False
10	High Cardinality Method	None
11	Transformed Train Set	(12860, 39)
12	Transformed Test Set	(3216, 39)
13	Shuffle Train-Test	True
14	Stratify Train-Test	False
15	Fold Generator	StratifiedKFold
16	Fold Number	10
17	CPU Jobs	-1
18	Use GPU	False
19	Log Experiment	False
20	Experiment Name	clf-default-name
21	USI	59b3
22	Imputation Type	simple
23	Iterative Imputation Iteration	None
24	Numeric Imputer	mean
25	Iterative Imputation Numeric Model	None
26	Categorical Imputer	constant
27	Iterative Imputation Categorical Model	None
28	Unknown Categoricals Handling	least_frequent
29	Normalize	True
30	Normalize Method	zscore
31	Transformation	False
32	Transformation Method	None
33	PCA	False
34	PCA Method	None
35	PCA Components	None
36	Ignore Low Variance	False
37	Combine Rare Levels	False
38	Rare Level Threshold	None
39	Numeric Binning	False
40	Remove Outliers	False
41	Outliers Threshold	None
42	Remove Multicollinearity	False
43	Multicollinearity Threshold	None
44	Clustering	False
45	Clustering Iteration	None
46	Polynomial Features	False
47	Polynomial Degree	None
48	Trignometry Features	False
49	Polynomial Threshold	None
50	Group Features	False
51	Feature Selection	False
52	Features Selection Threshold	None
53	Feature Interaction	False
54	Feature Ratio	False
55	Interaction Threshold	None
56	Fix Imbalance	False
57	Fix Imbalance Method	SMOTE

In [13]:
```python
compare_models(exclude=['catboost','lightgbm','lda','qda','mlp','nb','ridge'],fold=5)
```

	Model	Accuracy	AUC	Recall	Prec.	F1	Kappa	MCC	TT (Sec)
rf	Random Forest Classifier	0.9023	0.6633	0.0482	0.6523	0.0896	0.0770	0.1583	0.9220
xgboost	Extreme Gradient Boosting	0.9009	0.6631	0.0894	0.5261	0.1526	0.1273	0.1864	1.5920
lr	Logistic Regression	0.8995	0.6210	0.0016	0.1400	0.0031	0.0014	0.0078	1.5760
ada	Ada Boost Classifier	0.8994	0.6444	0.0062	0.3967	0.0122	0.0086	0.0370	0.5140
gbc	Gradient Boosting Classifier	0.8993	0.6611	0.0093	0.3645	0.0182	0.0133	0.0443	1.7480
svm	SVM - Linear Kernel	0.8981	0.0000	0.0093	0.0996	0.0170	0.0102	0.0167	0.0900
et	Extra Trees Classifier	0.8929	0.6315	0.0770	0.3466	0.1256	0.0924	0.1233	0.7740
knn	K Neighbors Classifier	0.8921	0.5676	0.0552	0.2974	0.0928	0.0632	0.0898	0.5380
dt	Decision Tree Classifier	0.8233	0.5514	0.2115	0.1779	0.1932	0.0948	0.0953	0.1300

Out[13]:
```
RandomForestClassifier(bootstrap=True, ccp_alpha=0.0, class_weight=None,
                       criterion='gini', max_depth=None, max_features='auto',
                       max_leaf_nodes=None, max_samples=None,
                       min_impurity_decrease=0.0, min_impurity_split=None,
                       min_samples_leaf=1, min_samples_split=2,
                       min_weight_fraction_leaf=0.0, n_estimators=100,
                       n_jobs=-1, oob_score=False, random_state=0, verbose=0,
                       warm_start=False)
```

In [14]:
```python
rf = create_model('rf', fold = 5)
```

	Accuracy	AUC	Recall	Prec.	F1	Kappa	MCC
0	0.9036	0.6749	0.0506	0.7647	0.0949	0.0835	0.1808
1	0.9032	0.6520	0.0623	0.6667	0.1139	0.0985	0.1834
2	0.9012	0.6607	0.0350	0.6000	0.0662	0.0558	0.1277
3	0.9016	0.6639	0.0428	0.6111	0.0800	0.0678	0.1431
4	0.9016	0.6648	0.0504	0.6190	0.0932	0.0793	0.1567
Mean	0.9023	0.6633	0.0482	0.6523	0.0896	0.0770	0.1583
SD	0.0009	0.0074	0.0091	0.0606	0.0159	0.0145	0.0215

In [15]:
```python
print(rf)
```

```
RandomForestClassifier(bootstrap=True, ccp_alpha=0.0, class_weight=None,
                       criterion='gini', max_depth=None, max_features='auto',
                       max_leaf_nodes=None, max_samples=None,
                       min_impurity_decrease=0.0, min_impurity_split=None,
                       min_samples_leaf=1, min_samples_split=2,
                       min_weight_fraction_leaf=0.0, n_estimators=100,
                       n_jobs=-1, oob_score=False, random_state=0, verbose=0,
                       warm_start=False)
```

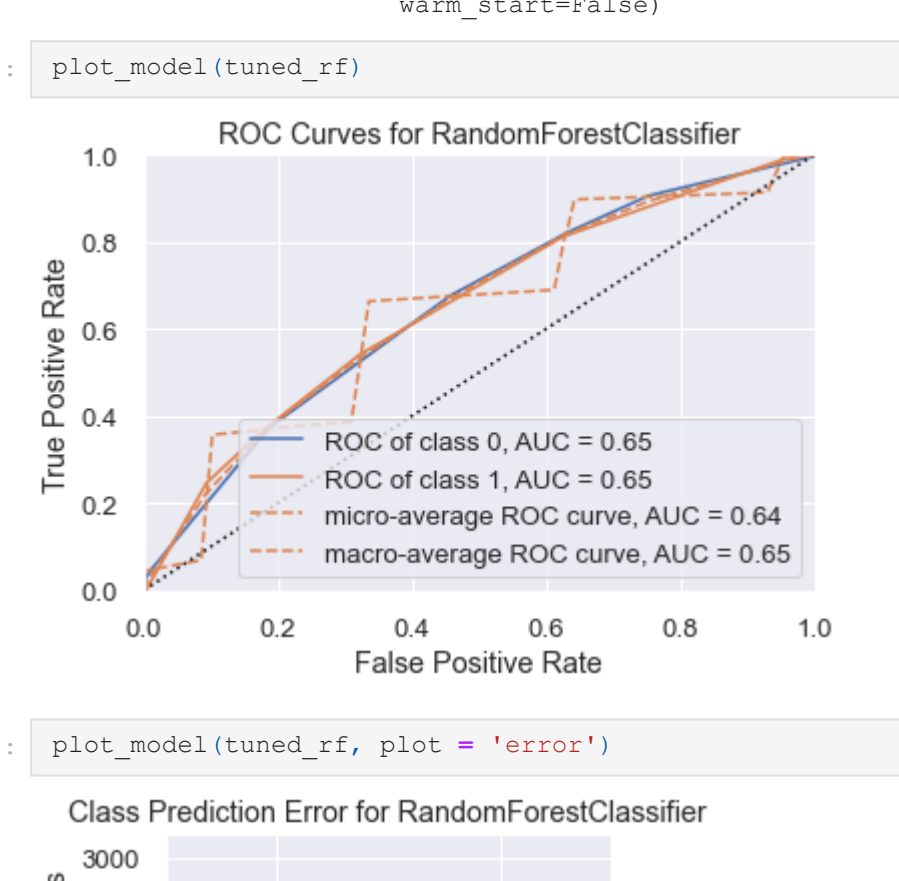
In [16]:
```python
tuned_rf = tune_model(rf, optimize='F1', fold=5)
```

	Accuracy	AUC	Recall	Prec.	F1	Kappa	MCC
0	0.6108	0.6276	0.5837	0.1437	0.2306	0.0836	0.1206
1	0.6474	0.6105	0.4864	0.1389	0.2161	0.0718	0.0953
2	0.6299	0.6206	0.5564	0.1458	0.2310	0.0863	0.1200
3	0.7026	0.6332	0.4591	0.1586	0.2358	0.1024	0.1248
4	0.7033	0.6358	0.4884	0.1664	0.2483	0.1160	0.1422
Mean	0.6588	0.6255	0.5148	0.1507	0.2323	0.0920	0.1206
SD	0.0379	0.0092	0.0471	0.0102	0.0103	0.0155	0.0150

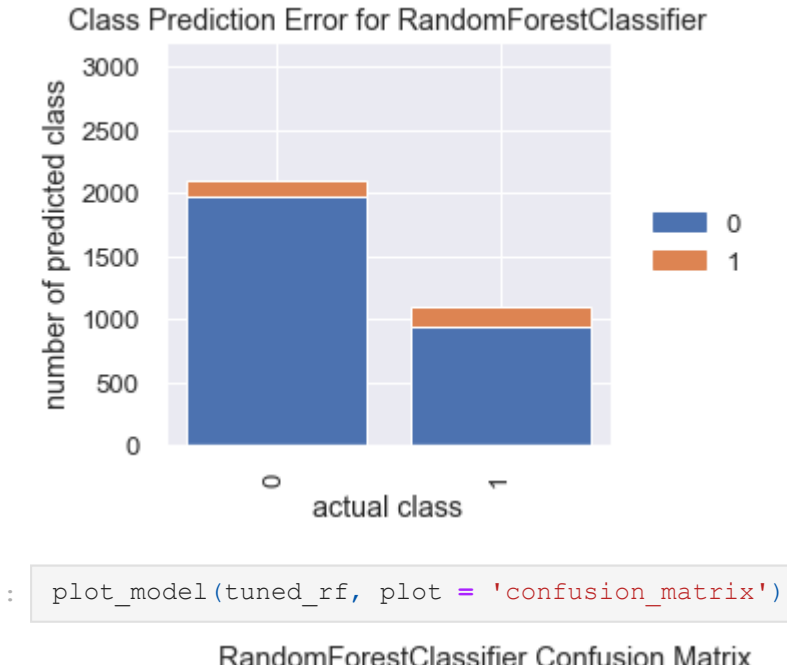
In [17]:
```python
print(tuned_rf)
```

```
RandomForestClassifier(bootstrap=False, ccp_alpha=0.0, class_weight='balanced',
                       criterion='entropy', max_depth=4, max_features=1.0,
                       max_leaf_nodes=None, max_samples=None,
                       min_impurity_decrease=0.001, min_impurity_split=None,
                       min_samples_leaf=2, min_samples_split=10,
                       min_weight_fraction_leaf=0.0, n_estimators=70, n_jobs=-1,
                       oob_score=False, random_state=0, verbose=0,
                       warm_start=False)
```

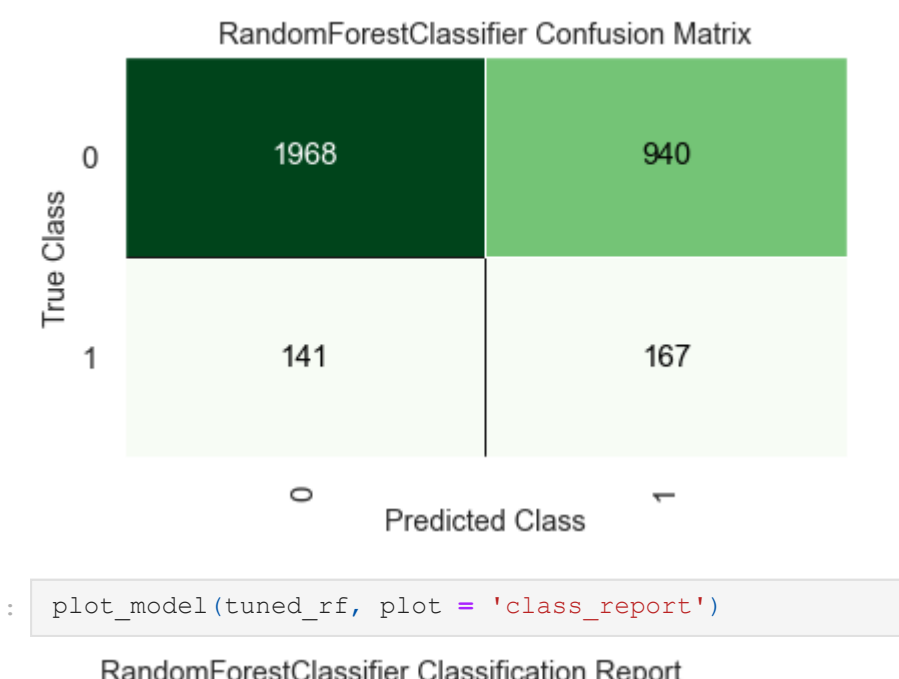
In [18]:
```python
plot_model(tuned_rf)
```



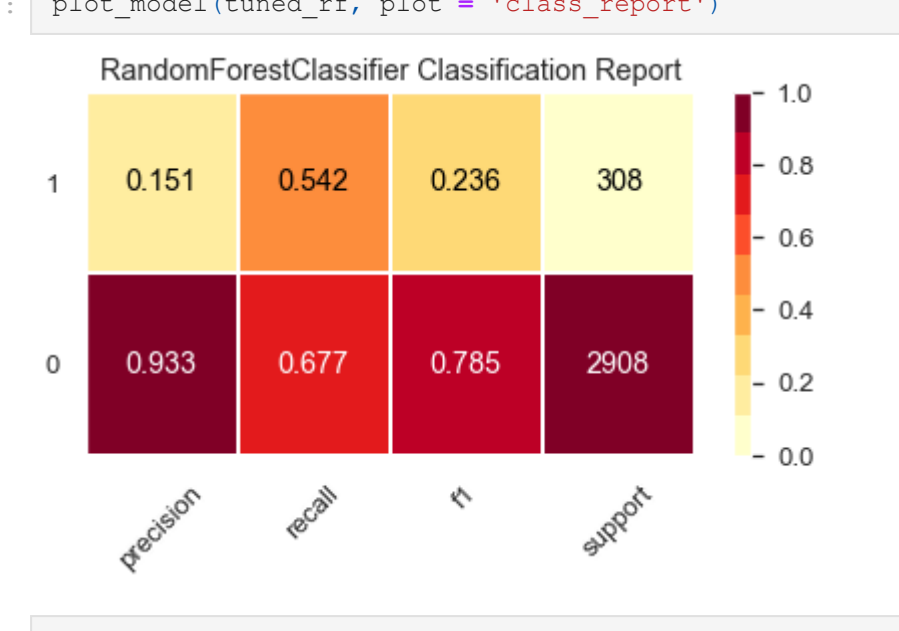
In [19]:
```python
plot_model(tuned_rf, plot = 'error')
```



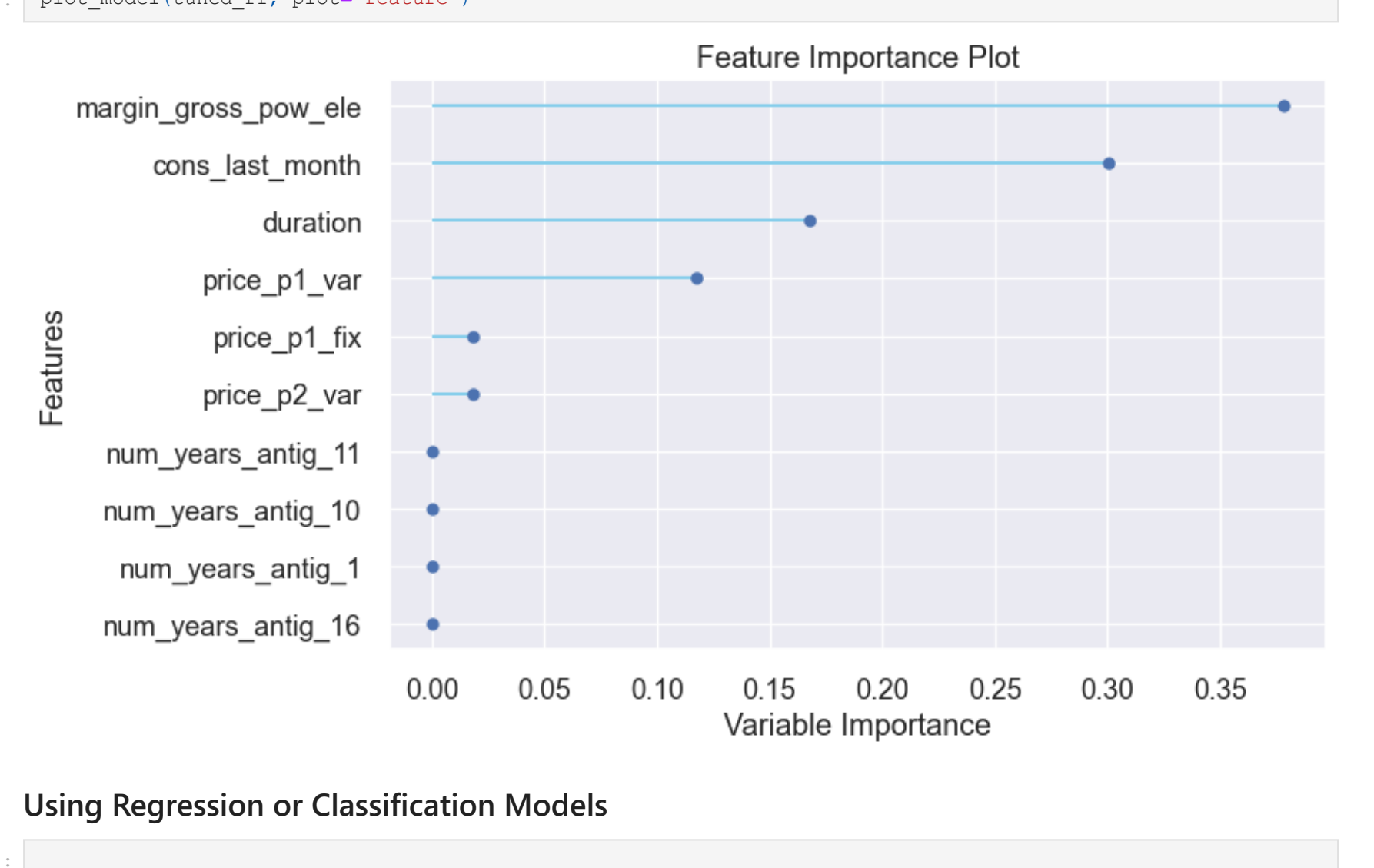
In [20]:
```python
plot_model(tuned_rf, plot = 'confusion_matrix')
```



In [21]:
```python
plot_model(tuned_rf, plot = 'class_report')
```



In [22]:
```python
plot_model(tuned_rf, plot='feature')
```



Using Regression or Classification Models

In [ ]:

In [ ]:

In [ ]:

Using XGBoost (Scikit-Learn)

Using RandomSearchCV

In [42]:
```python
model = XGBClassifier(random_state=0, n_estimators=100, objective='binary:logistic')
```

In [43]:
```python
parameters = {'max_depth': np.arange(3,10,1),
              'eta': np.arange(0.05,0.3,0.05),
              'n_estimators':np.arange(100,1000,100),
              'min_child_weight': np.arange(1,4,1),
              'gamma':np.arange(0,10,2),
              'subsample':np.arange(0.5,0.9,0.1),
              'colsample_bytree':np.arange(0.5,0.9,0.1),
              'reg_alpha':np.arange(0,1,0.1),
              'reg_lambda':np.arange(0,1,0.1)
             }
```

In [44]:
```python
randm = RandomizedSearchCV(estimator=model, param_distributions = parameters, cv = 5, n_iter = 10,
                           n_jobs=-1, scoring='f1')
```

In [45]:
```python
randm.fit(new_X,new_y)
```

```
[13:57:57] WARNING: C:/Users/Administrator/workspace/xgboost-win64_release_1.3.0/src/learner.cc:1061: Starti
ng in XGBoost 1.3.0, the default evaluation metric used with the objective 'binary:logistic' was changed fro
m 'error' to 'logloss'. Explicitly set eval_metric if you'd like to restore the old behavior.
```

Out[45]:
```
RandomizedSearchCV(cv=5, error_score=nan,
                   estimator=XGBClassifier(base_score=None, booster=None,
                                           colsample_bylevel=None,
                                           colsample_bynode=None,
                                           colsample_bytree=None, gamma=None,
                                           gpu_id=None, importance_type='gain',
                                           interaction_constraints=None,
                                           learning_rate=None,
                                           max_delta_step=None, max_depth=None,
                                           min_child_weight=None, missing=nan,
                                           monotone_constraints=None,
                                           n...
                                        'min_child_weight': array([1, 2, 3]),
                                        'n_estimators': array([100, 200, 300, 400, 500, 600, 700, 800, 90
0]),
                                        'reg_alpha': array([0. , 0.1, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8, 0.
9]),
                                        'reg_lambda': array([0. , 0.1, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8, 0.
9]),
                                        'subsample': array([0.5, 0.6, 0.7, 0.8])},
                   pre_dispatch='2*n_jobs', random_state=None, refit=True,
                   return_train_score=False, scoring='f1', verbose=0)
```

In [46]:
```python
randm.best_estimator_
```

Out[46]:
```
XGBClassifier(base_score=0.5, booster='gbtree', colsample_bylevel=1,
              colsample_bynode=1, colsample_bytree=0.6, eta=0.05, gamma=8,
              gpu_id=-1, importance_type='gain', interaction_constraints='',
              learning_rate=0.0500000007, max_delta_step=0, max_depth=8,
              min_child_weight=1, missing=nan, monotone_constraints='()',
              n_estimators=800, n_jobs=4, num_parallel_tree=1,
              objective='binary:logistic', random_state=0,
              reg_alpha=0.6000000000000001, reg_lambda=0.6000000000000001,
              scale_pos_weight=1, subsample=0.7999999999999999,
              tree_method='exact', use_label_encoder=True,
              validate_parameters=1, verbosity=None)
```

In [47]:
```python
randm.best_score_
```

Out[47]: 0.6233047729973467

In [48]:
```python
randm.best_params_
```

Out[48]:
```
{'subsample': 0.7999999999999999,
 'reg_lambda': 0.6000000000000001,
 'reg_alpha': 0.6000000000000001,
 'n_estimators': 800,
 'min_child_weight': 1,
 'max_depth': 8,
 'gamma': 8,
 'eta': 0.05,
 'colsample_bytree': 0.6}
```

Final Model

In [49]:
```python
xgbmodel = XGBClassifier(random_state=0, n_estimators=800, objective='binary:logistic',eta=0.05,colsample_by
                         subsample=0.8,reg_lambda=0.6,reg_alpha=0.6,min_child_weight=1,max_depth=8,gamma=8)
```

In [50]:
```python
xgbmodel.fit(X_train_scaled,y_train,eval_set=[(X_test_scaled,y_test)],eval_metric='logloss',early_stopping_r
```

```
[0]	validation_0-logloss:0.69037
[1]	validation_0-logloss:0.68638
[2]	validation_0-logloss:0.68404
[3]	validation_0-logloss:0.68257
[4]	validation_0-logloss:0.68183
[5]	validation_0-logloss:0.67988
[6]	validation_0-logloss:0.67819
[7]	validation_0-logloss:0.67602
[8]	validation_0-logloss:0.67371
[9]	validation_0-logloss:0.67186
[10]	validation_0-logloss:0.67061
[11]	validation_0-logloss:0.66937
[12]	validation_0-logloss:0.66754
[13]	validation_0-logloss:0.66597
[14]	validation_0-logloss:0.66438
[15]	validation_0-logloss:0.66311
[16]	validation_0-logloss:0.66275
[17]	validation_0-logloss:0.66068
[18]	validation_0-logloss:0.65958
[19]	validation_0-logloss:0.65879
[20]	validation_0-logloss:0.65841
[21]	validation_0-logloss:0.65821
[22]	validation_0-logloss:0.65711
[23]	validation_0-logloss:0.65677
[24]	validation_0-logloss:0.65605
[25]	validation_0-logloss:0.65559
[26]	validation_0-logloss:0.65465
[27]	validation_0-logloss:0.65281
[28]	validation_0-logloss:0.65255
```

```
[30]	validation_0-logloss:0.65198
[31]	validation_0-logloss:0.65105
[32]	validation_0-logloss:0.65022
[33]	validation_0-logloss:0.64990
[34]	validation_0-logloss:0.65043
[35]	validation_0-logloss:0.64988
[36]	validation_0-logloss:0.64975
[37]	validation_0-logloss:0.64986
[38]	validation_0-logloss:0.64938
[39]	validation_0-logloss:0.64928
[40]	validation_0-logloss:0.64929
[41]	validation_0-logloss:0.64914
[42]	validation_0-logloss:0.64804
[43]	validation_0-logloss:0.64805
[44]	validation_0-logloss:0.64788
[45]	validation_0-logloss:0.64731
[46]	validation_0-logloss:0.64737
[47]	validation_0-logloss:0.64738
[48]	validation_0-logloss:0.64740
[49]	validation_0-logloss:0.64733
[50]	validation_0-logloss:0.64698
[51]	validation_0-logloss:0.64641
[52]	validation_0-logloss:0.64641
[53]	validation_0-logloss:0.64641
[54]	validation_0-logloss:0.64648
[55]	validation_0-logloss:0.64624
[56]	validation_0-logloss:0.64624
[57]	validation_0-logloss:0.64624
[58]	validation_0-logloss:0.64622
[59]	validation_0-logloss:0.64620
[60]	validation_0-logloss:0.64620
[61]	validation_0-logloss:0.64627
[62]	validation_0-logloss:0.64628
[63]	validation_0-logloss:0.64629
[64]	validation_0-logloss:0.64631
[65]	validation_0-logloss:0.64573
[66]	validation_0-logloss:0.64570
[67]	validation_0-logloss:0.64570
[68]	validation_0-logloss:0.64572
[69]	validation_0-logloss:0.64571
[70]	validation_0-logloss:0.64570
[71]	validation_0-logloss:0.64536
[72]	validation_0-logloss:0.64535
[73]	validation_0-logloss:0.64535
[74]	validation_0-logloss:0.64536
[75]	validation_0-logloss:0.64530
[76]	validation_0-logloss:0.64531
[77]	validation_0-logloss:0.64533
[78]	validation_0-logloss:0.64537
[79]	validation_0-logloss:0.64536
[80]	validation_0-logloss:0.64518
[81]	validation_0-logloss:0.64518
[82]	validation_0-logloss:0.64516
[83]	validation_0-logloss:0.64518
[84]	validation_0-logloss:0.64519
[85]	validation_0-logloss:0.64518
[86]	validation_0-logloss:0.64465
[87]	validation_0-logloss:0.64466
[88]	validation_0-logloss:0.64450
[89]	validation_0-logloss:0.64432
[90]	validation_0-logloss:0.64432
[91]	validation_0-logloss:0.64411
[92]	validation_0-logloss:0.64358
[93]	validation_0-logloss:0.64358
[94]	validation_0-logloss:0.64298
[95]	validation_0-logloss:0.64256
[96]	validation_0-logloss:0.64258
[97]	validation_0-logloss:0.64257
[98]	validation_0-logloss:0.64254
[99]	validation_0-logloss:0.64254
[100]	validation_0-logloss:0.64227
[101]	validation_0-logloss:0.64227
[102]	validation_0-logloss:0.64229
[103]	validation_0-logloss:0.64233
[104]	validation_0-logloss:0.64233
[105]	validation_0-logloss:0.64218
[106]	validation_0-logloss:0.64215
[107]	validation_0-logloss:0.64215
[108]	validation_0-logloss:0.64219
[109]	validation_0-logloss:0.64216
[110]	validation_0-logloss:0.64210
[111]	validation_0-logloss:0.64212
[112]	validation_0-logloss:0.64211
[113]	validation_0-logloss:0.64209
[114]	validation_0-logloss:0.64211
[115]	validation_0-logloss:0.64209
[116]	validation_0-logloss:0.64209
[117]	validation_0-logloss:0.64207
[118]	validation_0-logloss:0.64209
[119]	validation_0-logloss:0.64208
[120]	validation_0-logloss:0.64209
[121]	validation_0-logloss:0.64209
[122]	validation_0-logloss:0.64212
[123]	validation_0-logloss:0.64213
[124]	validation_0-logloss:0.64214
[125]	validation_0-logloss:0.64214
[126]	validation_0-logloss:0.64214
[127]	validation_0-logloss:0.64213
```

Out[50]:
```
XGBClassifier(base_score=0.5, booster='gbtree', colsample_bylevel=1,
              colsample_bynode=1, colsample_bytree=0.6, eta=0.05, gamma=8,
              gpu_id=-1, importance_type='gain', interaction_constraints='',
              learning_rate=0.0500000007, max_delta_step=0, max_depth=8,
              min_child_weight=1, missing=nan, monotone_constraints='()',
              n_estimators=800, n_jobs=4, num_parallel_tree=1,
              objective='binary:logistic', random_state=0, reg_alpha=0.6,
              reg_lambda=0.6, scale_pos_weight=1, subsample=0.8,
              tree_method='exact', use_label_encoder=True,
              validate_parameters=1, verbosity=None)
```

In [51]:
```
y_pred = xgbmodel.predict(X_test_scaled)
```

In [52]:
```
y_pred
```

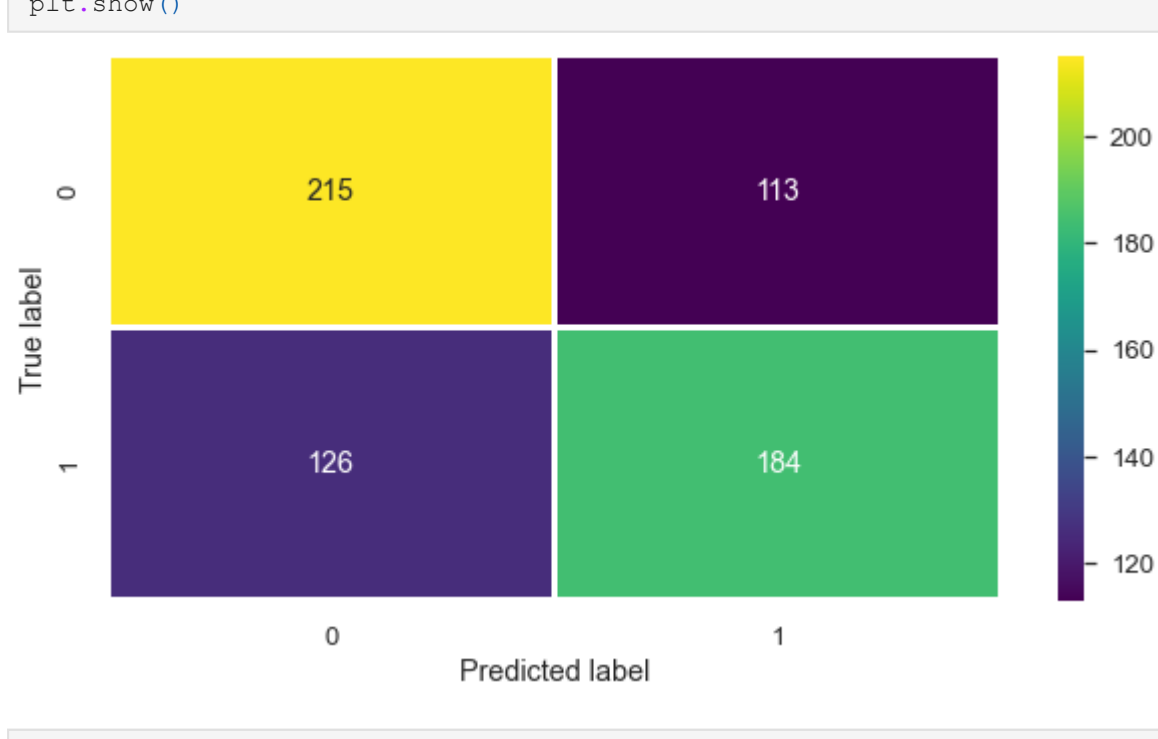
Out[52]:
```
array([1, 1, 1, 1, 0, 0, 1, 0, 0, 1, 1, 1, 0, 0, 1, 0, 1, 0, 1, 0, 1, 1,
       0, 0, 1, 0, 0, 1, 0, 1, 0, 0, 0, 0, 1, 0, 0, 0, 0, 0, 1, 0, 1, 1,
       0, 0, 0, 1, 1, 0, 1, 0, 1, 1, 0, 0, 1, 1, 0, 0, 1, 1, 0, 1, 1, 0,
       1, 0, 0, 1, 1, 1, 0, 1, 0, 1, 1, 0, 1, 0, 1, 0, 1, 0, 0, 1, 1, 1,
       1, 1, 1, 1, 1, 1, 1, 0, 1, 0, 0, 1, 0, 0, 1, 1, 1, 1, 1, 0, 1, 0,
       1, 1, 0, 1, 0, 0, 0, 0, 0, 1, 1, 0, 1, 0, 0, 1, 0, 0, 0, 0, 1, 1,
       1, 0, 0, 0, 1, 0, 1, 1, 0, 1, 0, 1, 1, 0, 1, 1, 1, 0, 0, 0, 1, 0,
       1, 1, 1, 0, 0, 1, 1, 0, 0, 0, 0, 0, 1, 0, 0, 0, 1, 0, 0, 0, 1, 0,
       0, 1, 0, 0, 0, 0, 1, 1, 1, 1, 0, 0, 1, 1, 0, 1, 0, 1, 0, 1, 0, 1,
       1, 0, 0, 0, 0, 0, 0, 1, 1, 1, 1, 1, 0, 0, 1, 1, 1, 1, 0, 1, 0, 1,
       0, 1, 1, 1, 1, 0, 0, 0, 0, 0, 0, 1, 0, 0, 0, 0, 0, 1, 1, 1, 0, 1,
       1, 0, 0, 0, 0, 1, 0, 0, 0, 0, 0, 1, 1, 1, 1, 0, 0, 0, 0, 0, 1, 1,
       0, 0, 1, 0, 0, 1, 0, 0, 1, 1, 1, 1, 0, 1, 1, 0, 1, 0, 0, 0, 1, 0,
       0, 0, 0, 0, 0, 1, 0, 1, 0, 1, 1, 1, 1, 1, 0, 0, 0, 0, 0, 0, 1, 0,
       0, 1, 1, 0, 0, 0, 1, 0, 1, 1, 1, 1, 0, 0, 1, 0, 0, 0, 0, 1, 1, 0,
       0, 1, 0, 0, 0, 0, 0, 0, 0, 1, 1, 1, 0, 1, 1, 0, 0, 1, 0, 0, 0, 1,
       1, 0, 1, 0, 0, 1, 0, 0, 1, 0, 0, 1, 0, 1, 0, 1, 0, 0, 1, 1, 0, 0,
       1, 0, 1, 1, 0, 1, 0, 1, 1, 0, 0, 0, 0, 0, 1, 0, 1, 0, 1, 1, 0, 0,
       0, 0, 1, 1, 1, 0, 0, 1, 1, 1, 1, 0, 0, 0, 0, 1, 1, 0, 1, 1, 1, 1,
       1, 1, 1, 1, 1, 0, 0, 1, 1, 0, 0, 1, 1, 1, 1, 0, 0, 1, 0, 1, 1, 1,
       0, 0, 0, 1, 0, 0, 1, 1, 0, 0, 1, 0, 0, 0, 0, 0, 0, 1, 0, 1, 1, 1,
       0, 0, 0, 1, 1, 1, 1, 0, 1, 1, 0, 0, 1, 0, 0, 1, 1, 0, 0, 1, 1, 0,
       0, 1, 1, 0, 0, 0, 1, 1, 0, 0, 1, 1, 1, 0, 0, 1, 1, 0, 0, 0, 1, 1,
       1, 1, 0, 1, 1, 0, 0, 1, 1, 0, 0, 0, 1, 0, 1, 0, 0, 0, 0, 0, 0, 1,
       0, 1, 1, 1, 0, 1, 0, 1, 0, 1, 1, 1, 1, 1, 0, 0, 1, 0, 1, 1, 1, 1,
       0, 1, 0, 0, 1, 0, 1, 0, 0, 1, 1, 0, 0, 0, 1, 0, 0, 0, 1, 1, 0, 1,
       0, 0, 0, 1, 0, 1, 0, 0, 0, 0, 0, 1, 1, 0, 0, 0, 1, 0, 1, 0, 0, 0,
       1, 0, 1, 0, 0, 0, 0, 1, 1, 0, 0, 1, 1, 0, 0, 0, 0, 1, 1, 1, 0, 1,
       0, 1, 0, 0, 1, 0, 0, 1, 0, 1, 0, 1, 0, 1, 1, 0, 1, 0, 0, 0, 0, 0],
      dtype=int64)
```

Model Evaluation

In [53]:
```
cm = confusion_matrix(y_test,y_pred)
cm
```

Out[53]:
```
array([[215, 113],
       [126, 184]], dtype=int64)
```

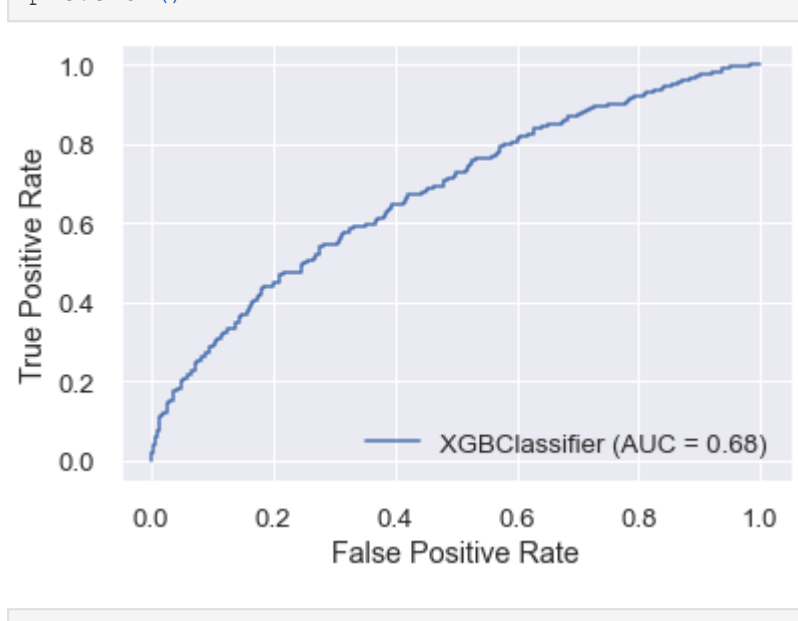
In [54]:
```
fig , ax = plt.subplots(figsize=(10,5))
sns.heatmap(cm, annot=True,fmt='.4g',linewidths=2, cmap='viridis')
plt.ylabel('True label')
plt.xlabel('Predicted label')
plt.show()
```



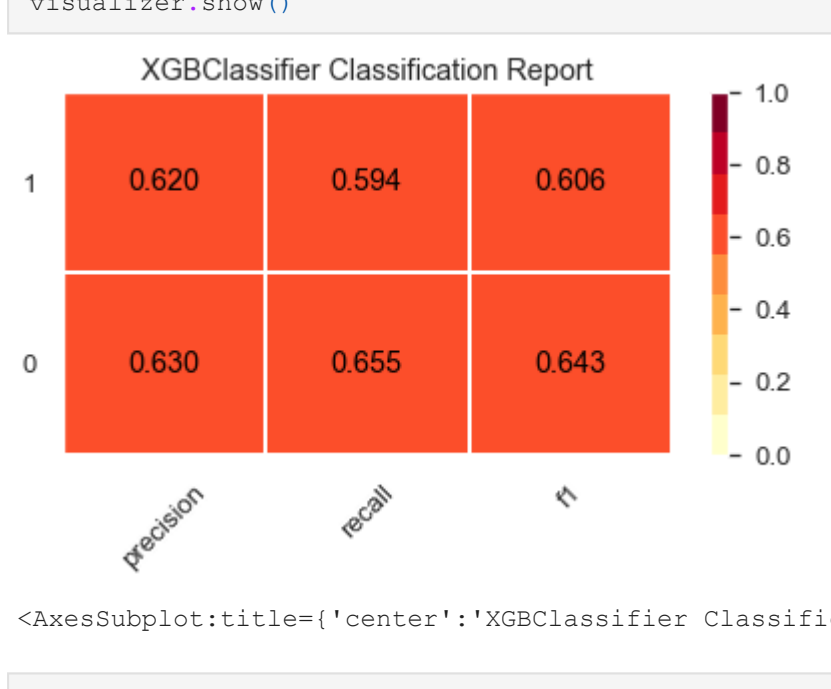
In [55]:
```
print(classification_report(y_test,y_pred))
```

```
              precision    recall  f1-score   support

           0       0.63      0.66      0.64       328
           1       0.62      0.59      0.61       310

    accuracy                           0.63       638
   macro avg       0.63      0.62      0.62       638
weighted avg       0.63      0.63      0.63       638
```

In [56]:
```
plot_roc_curve(xgbmodel,X_test_scaled,y_test)
plt.show()
```



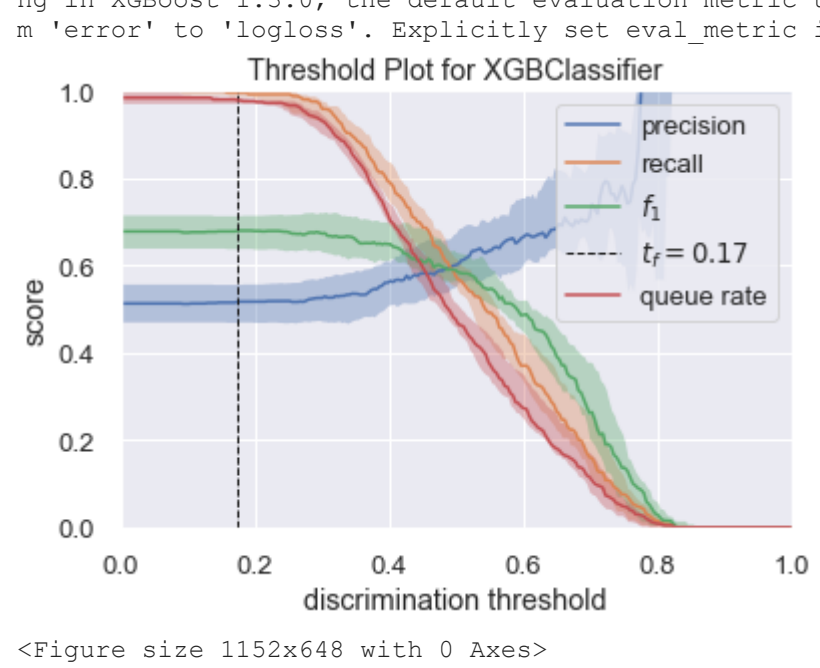
In [57]:
```
visualizer = ClassificationReport(model=xgbmodel)
visualizer.fit(X_train_scaled,y_train)
visualizer.score(X_test_scaled,y_test)
visualizer.show()
```



Out[57]:
```
<AxesSubplot:title={'center':'XGBClassifier Classification Report'}>
```

In [58]:
```
visualizer = DiscriminationThreshold(model=xgbmodel, random_state=0, n_trials=10)
visualizer.fit(X_train_scaled,y_train)
visualizer.score(X_test_scaled,y_test)
plt.figure(figsize=(16,9))
visualizer.show()
```

```
[14:01:10] WARNING: C:/Users/Administrator/workspace/xgboost-win64_release_1.3.0/src/learner.cc:1061: Starti
ng in XGBoost 1.3.0, the default evaluation metric used with the objective 'binary:logistic' was changed fro
m 'error' to 'logloss'. Explicitly set eval_metric if you'd like to restore the old behavior.
[14:01:14] WARNING: C:/Users/Administrator/workspace/xgboost-win64_release_1.3.0/src/learner.cc:1061: Starti
ng in XGBoost 1.3.0, the default evaluation metric used with the objective 'binary:logistic' was changed fro
m 'error' to 'logloss'. Explicitly set eval_metric if you'd like to restore the old behavior.
[14:01:17] WARNING: C:/Users/Administrator/workspace/xgboost-win64_release_1.3.0/src/learner.cc:1061: Starti
ng in XGBoost 1.3.0, the default evaluation metric used with the objective 'binary:logistic' was changed fro
m 'error' to 'logloss'. Explicitly set eval_metric if you'd like to restore the old behavior.
[14:01:21] WARNING: C:/Users/Administrator/workspace/xgboost-win64_release_1.3.0/src/learner.cc:1061: Starti
ng in XGBoost 1.3.0, the default evaluation metric used with the objective 'binary:logistic' was changed fro
m 'error' to 'logloss'. Explicitly set eval_metric if you'd like to restore the old behavior.
[14:01:24] WARNING: C:/Users/Administrator/workspace/xgboost-win64_release_1.3.0/src/learner.cc:1061: Starti
ng in XGBoost 1.3.0, the default evaluation metric used with the objective 'binary:logistic' was changed fro
m 'error' to 'logloss'. Explicitly set eval_metric if you'd like to restore the old behavior.
[14:01:28] WARNING: C:/Users/Administrator/workspace/xgboost-win64_release_1.3.0/src/learner.cc:1061: Starti
ng in XGBoost 1.3.0, the default evaluation metric used with the objective 'binary:logistic' was changed fro
m 'error' to 'logloss'. Explicitly set eval_metric if you'd like to restore the old behavior.
[14:01:32] WARNING: C:/Users/Administrator/workspace/xgboost-win64_release_1.3.0/src/learner.cc:1061: Starti
ng in XGBoost 1.3.0, the default evaluation metric used with the objective 'binary:logistic' was changed fro
m 'error' to 'logloss'. Explicitly set eval_metric if you'd like to restore the old behavior.
[14:01:35] WARNING: C:/Users/Administrator/workspace/xgboost-win64_release_1.3.0/src/learner.cc:1061: Starti
ng in XGBoost 1.3.0, the default evaluation metric used with the objective 'binary:logistic' was changed fro
m 'error' to 'logloss'. Explicitly set eval_metric if you'd like to restore the old behavior.
[14:01:38] WARNING: C:/Users/Administrator/workspace/xgboost-win64_release_1.3.0/src/learner.cc:1061: Starti
ng in XGBoost 1.3.0, the default evaluation metric used with the objective 'binary:logistic' was changed fro
m 'error' to 'logloss'. Explicitly set eval_metric if you'd like to restore the old behavior.
[14:01:41] WARNING: C:/Users/Administrator/workspace/xgboost-win64_release_1.3.0/src/learner.cc:1061: Starti
ng in XGBoost 1.3.0, the default evaluation metric used with the objective 'binary:logistic' was changed fro
m 'error' to 'logloss'. Explicitly set eval_metric if you'd like to restore the old behavior.
```




```
<Figure size 1152x648 with 0 Axes>
```

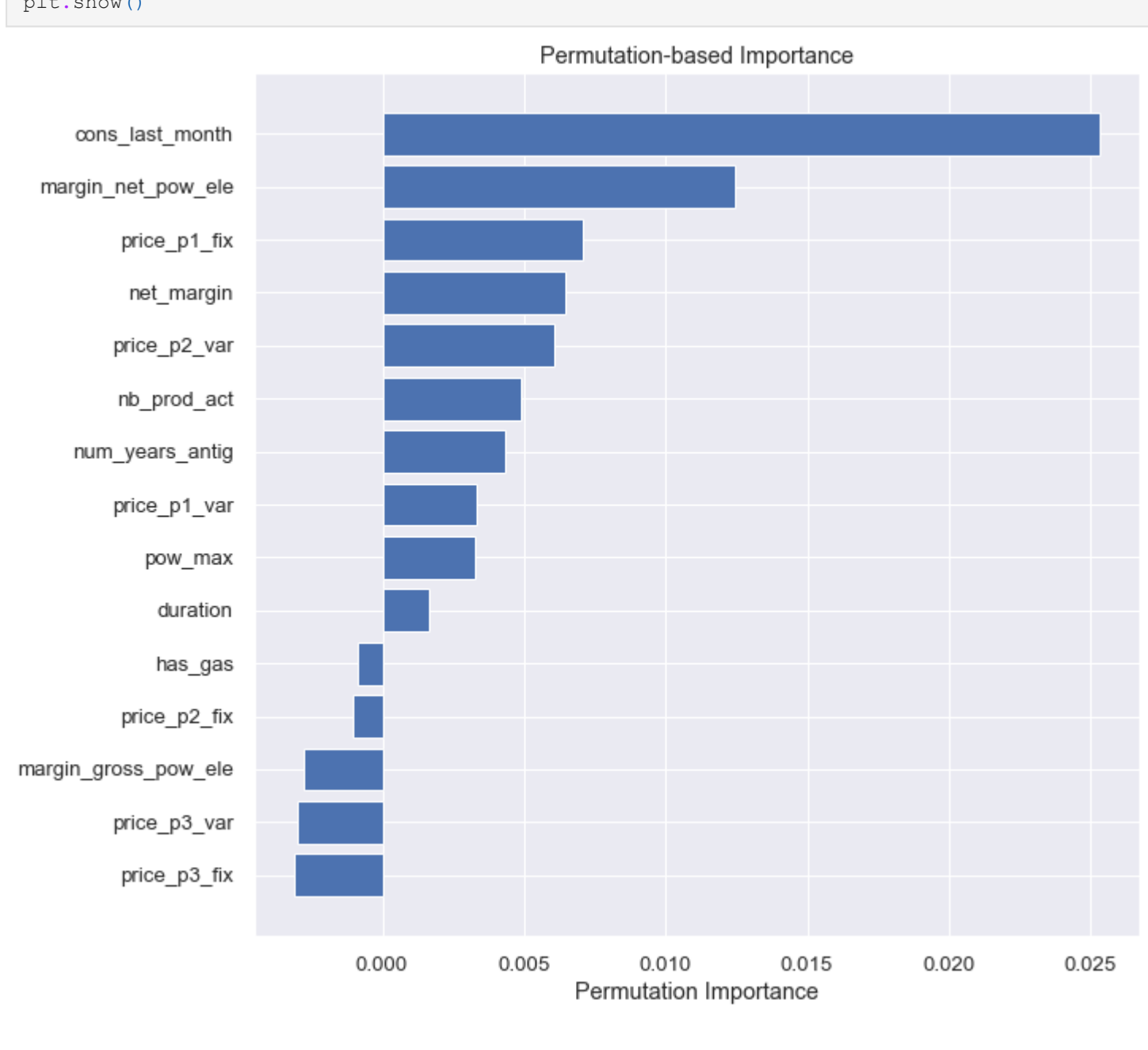
Out[58]:
```
<AxesSubplot:title={'center':'Threshold Plot for XGBClassifier'}, xlabel='discrimination threshold', ylabel
='score'>
```

In [ ]:

The permutation based importance

In [59]:
```
perm_importance = permutation_importance(xgbmodel,X_test_scaled,y_test, random_state=0, scoring='f1')
```

In [60]:
```
sorted_idx = perm_importance.importances_mean.argsort()
plt.figure(figsize=(10,10))
plt.title("Permutation-based Importance")
plt.barh(X.columns[sorted_idx], perm_importance.importances_mean[sorted_idx])
plt.xlabel("Permutation Importance")
plt.show()
```

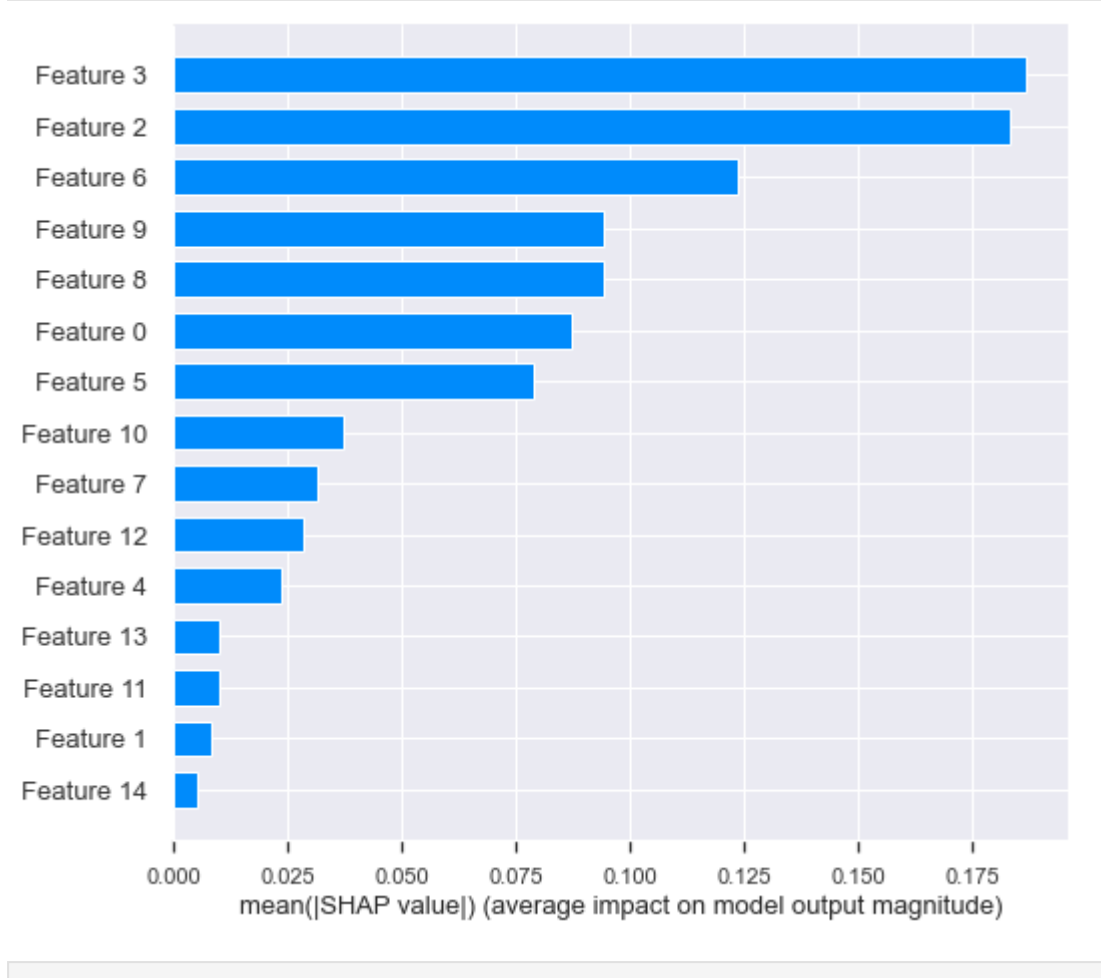


Compute Importance from SHAP Values

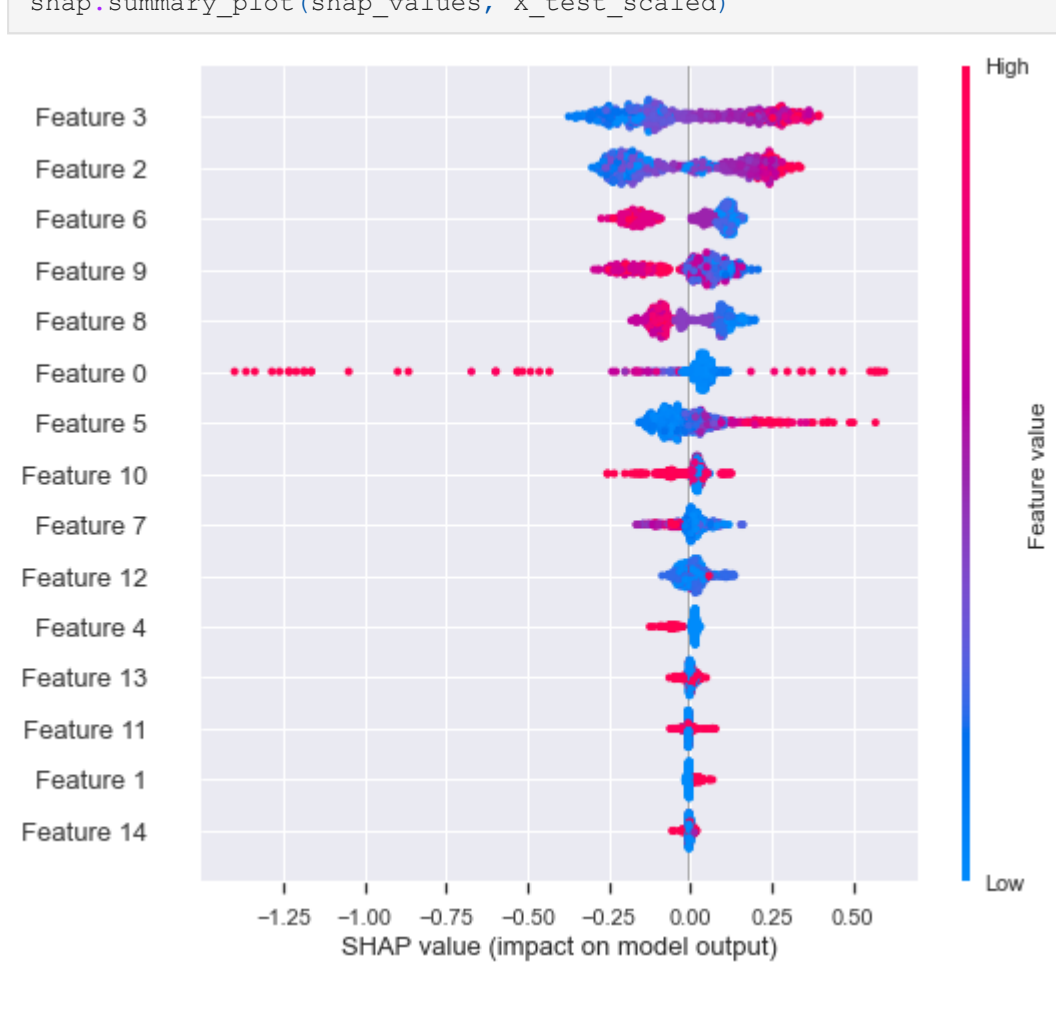
In [61]:
```
explainer = shap.TreeExplainer(xgbmodel)
```

In [63]:
```
shap_values = explainer.shap_values(X_test_scaled)
```

In [64]:
```
shap.summary_plot(shap_values, X_test_scaled, plot_type="bar")
```



In [65]:
```
shap.summary_plot(shap_values, X_test_scaled)
```



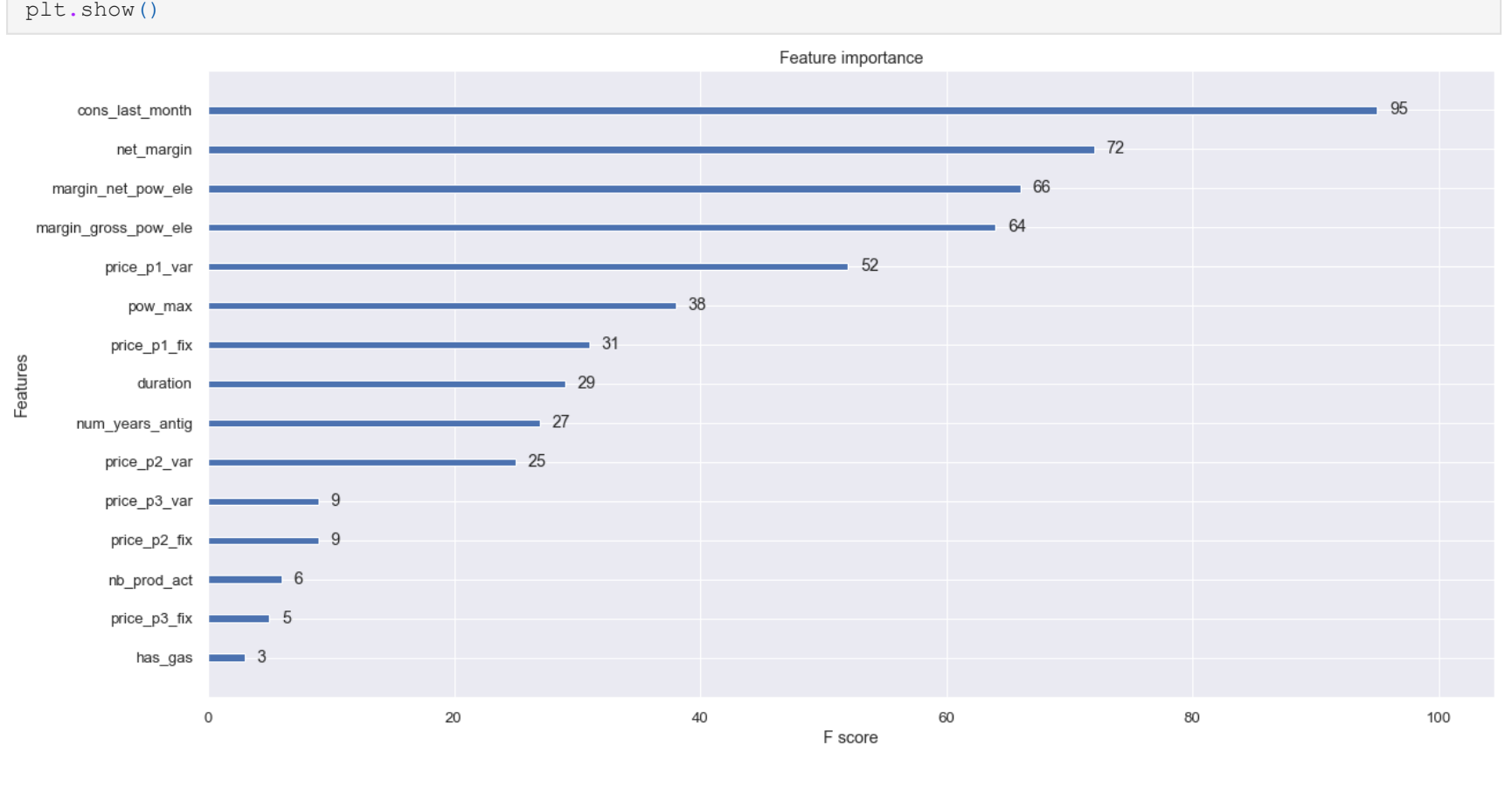
Available importance_types = ['weight', 'gain', 'cover', 'total_gain', 'total_cover']

In [66]:
```
new_X.columns
```

Out[66]:
```
Index(['cons_last_month', 'has_gas', 'margin_gross_pow_ele', 'margin_net_pow_ele', 'nb_prod_act', 'net_margi
n', 'num_years_antig', 'pow_max', 'duration', 'price_p1_var', 'price_p2_var', 'price_p3_var', 'price_p1_fi
x', 'price_p2_fix', 'price_p3_fix'], dtype='object')
```

In [67]:
```
xgbmodel.get_booster().feature_names = ['cons_last_month', 'has_gas', 'margin_gross_pow_ele', 'margin_net_po
```

In [68]:
```
fig, ax = plt.subplots(figsize=(20,10))
xgb.plot_importance(xgbmodel.get_booster(),ax=ax)
plt.show()
```



Cross-Validation

In [70]:
```
cv = cross_val_score(xgbmodel,new_X,new_y,cv=5,verbose=1,scoring='f1')
```

```
[Parallel(n_jobs=1)]: Using backend SequentialBackend with 1 concurrent workers.
[14:03:58] WARNING: C:/Users/Administrator/workspace/xgboost-win64_release_1.3.0/src/learner.cc:1061: Starti
ng in XGBoost 1.3.0, the default evaluation metric used with the objective 'binary:logistic' was changed fro
m 'error' to 'logloss'. Explicitly set eval_metric if you'd like to restore the old behavior.
[14:04:01] WARNING: C:/Users/Administrator/workspace/xgboost-win64_release_1.3.0/src/learner.cc:1061: Starti
ng in XGBoost 1.3.0, the default evaluation metric used with the objective 'binary:logistic' was changed fro
m 'error' to 'logloss'. Explicitly set eval_metric if you'd like to restore the old behavior.
[14:04:04] WARNING: C:/Users/Administrator/workspace/xgboost-win64_release_1.3.0/src/learner.cc:1061: Starti
ng in XGBoost 1.3.0, the default evaluation metric used with the objective 'binary:logistic' was changed fro
m 'error' to 'logloss'. Explicitly set eval_metric if you'd like to restore the old behavior.
[14:04:07] WARNING: C:/Users/Administrator/workspace/xgboost-win64_release_1.3.0/src/learner.cc:1061: Starti
ng in XGBoost 1.3.0, the default evaluation metric used with the objective 'binary:logistic' was changed fro
m 'error' to 'logloss'. Explicitly set eval_metric if you'd like to restore the old behavior.
[14:04:10] WARNING: C:/Users/Administrator/workspace/xgboost-win64_release_1.3.0/src/learner.cc:1061: Starti
ng in XGBoost 1.3.0, the default evaluation metric used with the objective 'binary:logistic' was changed fro
m 'error' to 'logloss'. Explicitly set eval_metric if you'd like to restore the old behavior.
[Parallel(n_jobs=1)]: Done   5 out of   5 | elapsed:   15.4s finished
```

In [71]:
```
cv.mean()
```

Out[71]:
```
0.6233047729973467
```

In [ ]: