Machine Learning Project with Company Bankruptcy Prediction !

Goal : The main goal of this project is to use several BASELINE machine learning techniques such as ,KNN, LR, SVM etc. to identify whether the company with different accounting indicator has bankrupted or not and compare the f1-score for Bankruptcy with these techniques to find the best one.The reason that I did not do much optimal hyperparameter searching is because I first constucted a hyperparameter grid and applied like GridSearch and Recursive Feature Elimination (aka RFE) to find the optimas but it costs too much computer powers and my laptop was complaining me in angrt.But I do tried several models to apply GridSearch, pusedocodes as follows:

```
params = [{'kernel': ['rbf'], 'gamma': [1e-3, 1e-4],
                    'C': [1, 10, 100, 1000]},
                    {'kernel': ['linear'], 'C': [1, 10, 100, 1000]}]


svm = SVC(probability = True)
svm = GridSearchCV(svm, params)
```

Tasks:

1. Split the data provided in the previous link into training, validation, and testing sets.
2. Analyze these data sets using different methods we learned in our class. You are expected to use at least three methods.
3. Report the performance (accuracy, F1-score, AUC) for each of your algorithms on the testing data.

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Potential problems with dataset

For example:

- **To many X-variables**
- **Unbalanced class**
- **Variables probably correlated**
- **Latent outliers**

ML techniques used:

There are the links that you can quickly navigate to the overall evaluations like AUC, ROC curve and so on.

- DNN
- LogisticRegression
- SVM
- KNN
- XGBoost
- DecisionTree
- RandomForest
- GradientBoosting
- MLP
- CatBoostClassifier

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FinalResults

Method	Accuracy	Precision	Recall	AUC	F1-score (Label = 1)
DNN	0.96	0.92	1.00	0.96	**0.09**
LR	0.91	0.91	0.92	0.96	**0.29**
SVM	0.91	0.90	0.93	0.97	**0.24**
KNN	0.95	0.91	1.00	0.98	**0.24**
XGBoost	0.99	0.98	1.00	1.00	**0.53**
DecisionTree	0.94	0.93	0.96	0.94	**0.33**
RandomForest	0.98	0.96	1.00	1.00	**0.25**
GradientBoosting	0.95	0.94	0.97	0.99	**0.38**
MLP	0.95	0.93	0.98	0.98	**0.25**
CatBoosting	0.98	0.97	1.00	1.00	**0.33**

There is no doubt that the XGBoost wins this game!!!!!

Packages

In [1]:
```
import warnings
warnings.filterwarnings("ignore")

import numpy as np
import pandas as pd

import seaborn as sns
sns.set(style="darkgrid")
import matplotlib.pyplot as plt
from xgboost import plot_tree, plot_importance

from sklearn.model_selection import train_test_split
import scikitplot as skplt # Package for ROC vurve
from sklearn.metrics import confusion_matrix, classification_report, plot_confusion_matrix, f1_score,auc,roc_curve,roc_auc_scor
e, precision_recall_curve

from sklearn.metrics import precision_score, recall_score, f1_score
from sklearn.metrics import accuracy_score
from sklearn import metrics

from xgboost import XGBClassifier
from sklearn.neighbors import KNeighborsClassifier
from sklearn.linear_model import LogisticRegression
from sklearn.naive_bayes import MultinomialNB
from sklearn.svm import SVC
from imblearn.over_sampling import SMOTE
from sklearn.preprocessing import MinMaxScaler
from sklearn.preprocessing import StandardScaler
from sklearn.model_selection import GridSearchCV
from sklearn.tree import DecisionTreeClassifier
from sklearn.ensemble import RandomForestClassifier
from sklearn.ensemble import GradientBoostingClassifier
from sklearn.neural_network import MLPClassifier
from sklearn.linear_model import SGDClassifier
from catboost import CatBoostClassifier

import tensorflow as tf
from tensorflow.keras.models import Sequential
from tensorflow.keras.layers import Dense, Activation,Dropout
from tensorflow.keras.callbacks import EarlyStopping

from sklearn.decomposition import PCA
```

Enveloped Model Evaluation Functions

In [2]:
```
def evaluation(y_true, y_pred):
    precision_micro = precision_score(y_true, y_pred, average='micro')
    recall_micro = recall_score(y_true, y_pred, average='micro')
    f1_micro = f1_score(y_true, y_pred, average='micro')
    print(100*"*")
    print("precision_micro:",precision_micro,end="\t")
    print("recall_micro:",recall_micro,end="\t")
    print("f1_micro:",f1_micro)
    precision_macro = precision_score(y_true, y_pred, average='macro')
    recall_macro = recall_score(y_true, y_pred, average='macro')
    f1_macro = f1_score(y_true, y_pred, average='macro')
    print("precision_macro:",precision_macro,end="\t")
    print("recall_macro:",recall_macro,end="\t")
    print("f1_macro:",f1_macro)
    print(100*"*")

    return f1_macro

def model_eval(algo,X_train,y_train,X_test,y_test):
    algo.fit(X_train,y_train)
    y_train_ypred = algo.predict(X_train)
    y_train_prob = algo.predict_proba(X_train)[:,-1]

    #TEST
    y_test_ypred = algo.predict(X_test)
    y_test_prob = algo.predict_proba(X_test)[:,-1]
    y_probas = algo.predict_proba(X_test)
    auc = metrics.roc_auc_score(y_test,y_test_prob)
    print("auc:",auc)
    acc_score = accuracy_score(y_test, y_test_ypred)
    print("accuracy score:",acc_score)
    #Confussion Matrix
    plot_confusion_matrix(algo, X_test, y_test)
#   plt.show()
    print('='*100)
    evaluation(y_test,y_test_ypred)
    print('='*100)
    print('Classification Report: \n', classification_report(y_test, y_test_ypred, digits=3))
    print('='*100)

#     ROC Curve
    fpr,tpr,thresholds = roc_curve(y_test,y_test_prob)
    skplt.metrics.plot_roc(y_test, y_probas,figsize=(8,6) )

#     PR Curve
    skplt.metrics.plot_precision_recall(y_test, y_probas, figsize=(8,6))
```

ExploratoryDataAnalysis

In [3]:
```
data = pd.read_csv("./data/data.csv",encoding="utf_8_sig")
data.head()
```

Out[3]:

	Bankrupt?	ROA(C) before interest and depreciation before interest	ROA(A) before interest and % after tax	ROA(B) before interest and depreciation after tax	Operating Gross Margin	Realized Sales Gross Margin	Operating Profit Rate	Pre-tax net Interest Rate	After-tax net Interest Rate	Non-industry income and expenditure/revenue	...	Net Income to Total Assets	Tot asse to GN pri
0	1	0.370594	0.424389	0.405750	0.601457	0.601457	0.998969	0.796887	0.808809	0.302646	...	0.716845	0.0092
1	1	0.464291	0.538214	0.516730	0.610235	0.610235	0.998946	0.797380	0.809301	0.303556	...	0.795297	0.0083
2	1	0.426071	0.499019	0.472295	0.601450	0.601364	0.998857	0.796403	0.808388	0.302035	...	0.774670	0.0400
3	1	0.399844	0.451265	0.457733	0.583541	0.583541	0.998700	0.796967	0.808966	0.303350	...	0.739555	0.0032
4	1	0.465022	0.538432	0.522298	0.598783	0.598783	0.998973	0.797366	0.809304	0.303475	...	0.795016	0.0038

5 rows × 96 columns

Missing Values

In [4]:
```
missing = data.isna().sum(axis = 1).reset_index();missing.columns = ['Variables','Missing Value']
missing = missing.sort_values("Missing Value",ascending = False)
if ((missing["Missing Value"] > 0 ).sum()) == 0:
    print("There is no missing values in dataset")
missing
```

```
There is no missing values in dataset
```

Out[4]:

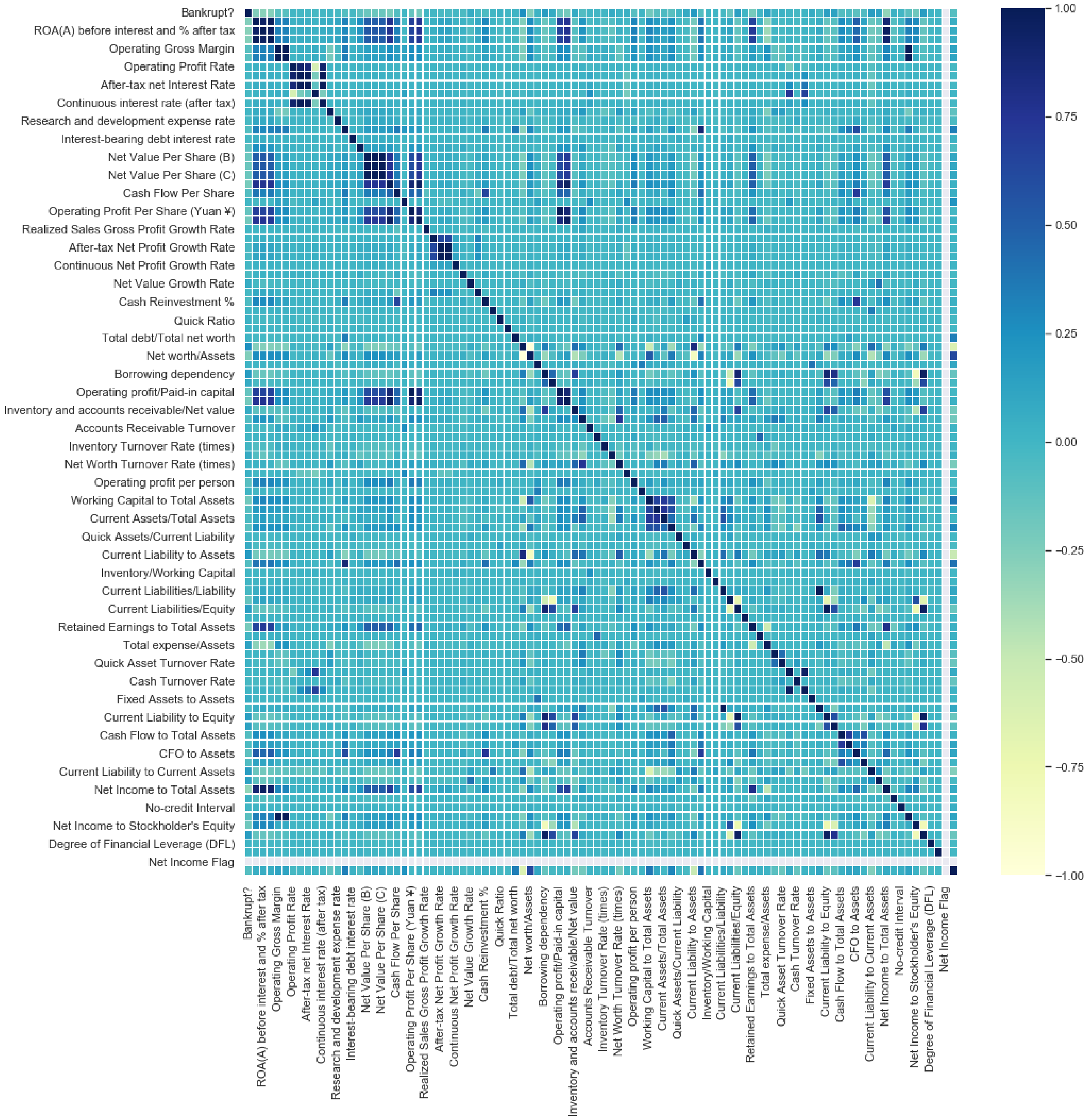
	Variables	Missing Value
0	0	0
4554	4554	0
4552	4552	0
4551	4551	0
4550	4550	0
...	...	...
2270	2270	0
2269	2269	0
2268	2268	0
2267	2267	0
6818	6818	0

6819 rows × 2 columns

Correlation Map

In [5]:
```python
fig, ax = plt.subplots(figsize = (15,15))
sns.heatmap(data.corr(), ax = ax, cmap = 'YlGnBu', linewidth = 0.1)
```

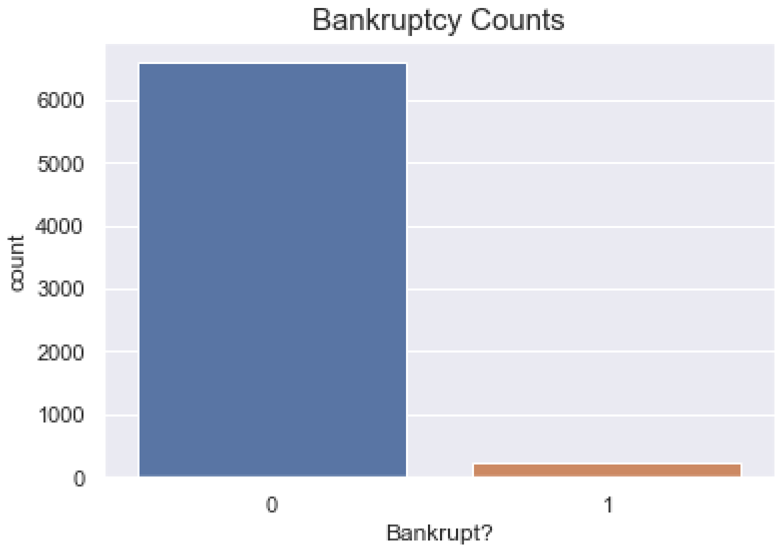
Out[5]: <matplotlib.axes._subplots.AxesSubplot at 0x28db4322d08>

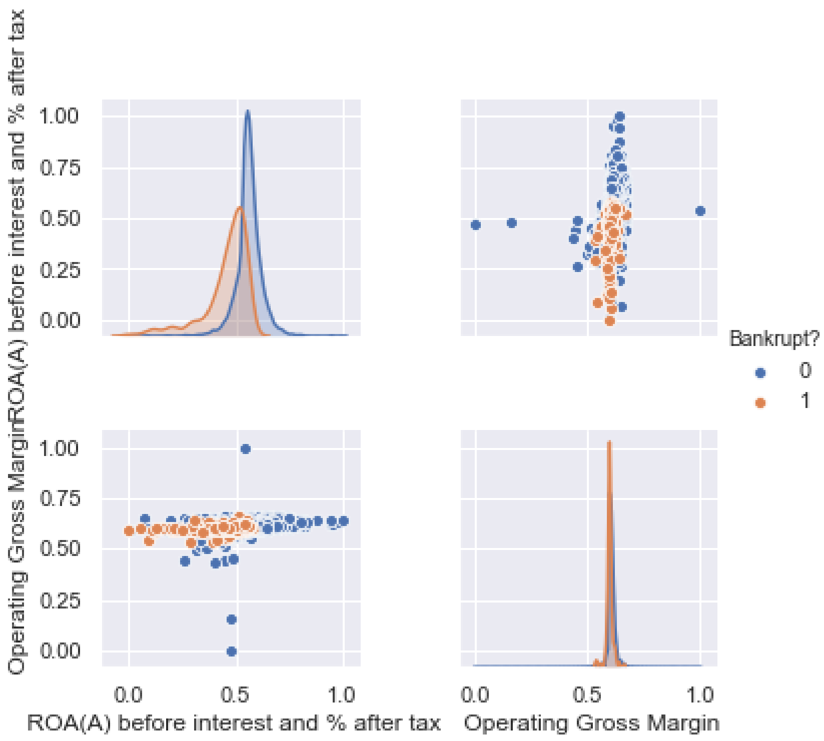


Class imbalance

There is a imbalance in our data, we should focus on "Label == 1" f1-score.

In [43]:
```
sns.countplot(data=data, x='Bankrupt?')
plt.title('Bankruptcy Counts', fontsize = 15)
plt.show()

pair = sns.pairplot(data = data.iloc[:,0:5:2], hue = 'Bankrupt?')
plt.show()
```



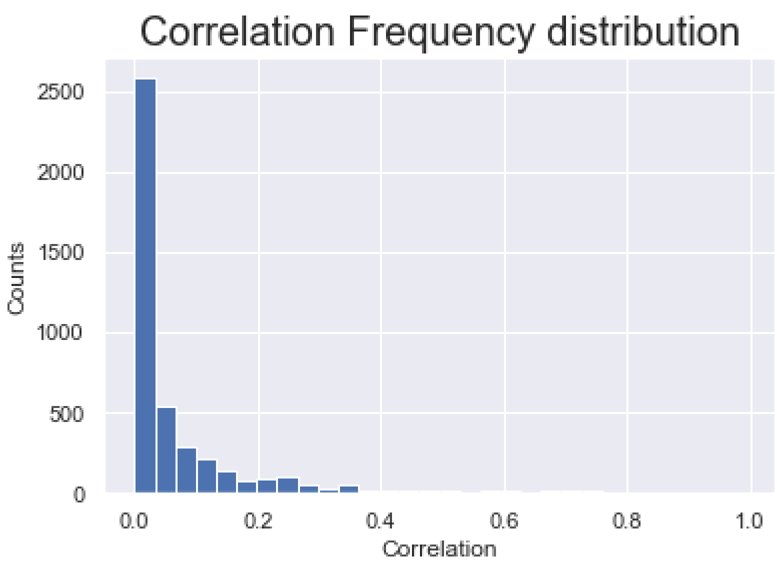


In [262]:
```
X = data.drop(["Bankrupt?"],axis=1)
y = data["Bankrupt?"].values
```

Most of the features are uncorrelated with each other but there are also few of them correlated

so that we could use PCA to reduce the dimension.

In [263]:
```
def correlation_counts(data):
    cormet = data.corr().round(3).abs()
    upper_tri = np.triu_indices(n=cormet.shape[0])
    corr_v = cormet.to_numpy()[upper_tri]
    plt.hist(x=corr_v, bins=30, range=[0.00, 0.99])
    plt.xlabel("Correlation")
    plt.ylabel("Counts")
    plt.grid(True)
    plt.title("Correlation Frequency distribution", fontsize = 20)
    plt.show()

correlation_counts(X)
```



Oversampling

In [264]:
```
# using smote oversampling to correct unbalanced data
#smote = SMOTE()
#X,y=smote.fit_resample(X,y)
#sns.countplot(x=y)
#plt.title('Bankruptcy Counts after Correction', fontsize = 15)
#plt.show()

#Split data into 60:20:20
#x_train, x_test, y_train, y_test = train_test_split(X,y,test_size=0.2,stratify=y,random_state=42)
#x_train,x_valid, y_train, y_valid = train_test_split(x_train,y_train,test_size=0.25,stratify=y_train,random_state=42)

#print(x_train.shape)
#print(x_valid.shape)
#print(x_test.shape)

#len(X)/len(y) == 1 #True for data is balanced
```

OutliersRemoval

In [265]:
```
#def rm_outliers(data):
    #data = sorted(data)
    #Q1,Q3 = np.percentile(data,[25,75])
    #IQR = Q3 - Q1
    #low = Q1 - IQR * 1.5
    #up = Q3 + IQR * 1.5
    #return low,up

#Update data which value exceed upper or lower bound to its upper or lower bound!
#def update(data):
    #for i in data.columns:
        #low,up = rm_outliers(data[i])
        #data[i] = np.where(data[i] > up, up, data[i])
        #data[i] = np.where(data[i] < low, low, data[i])
        #return data

#X = update(X)
#X.plot(kind="box",figsize = (18, 5))
#plt.xticks([])
#print("WE ARE DONE WITH OUTLIERS!")
```

Scaling

Scaling data for DNN

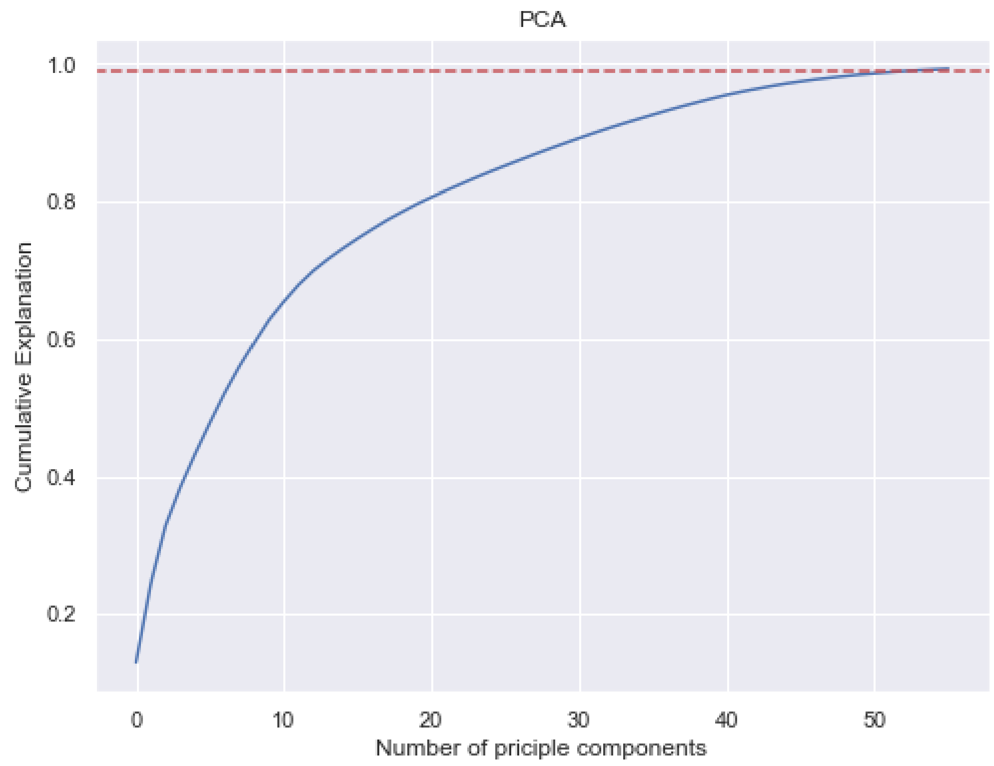
In [266]:
```
# Use MinMaxScaler to scale data since there are huge ranges between those data
# We need this scaling for DNN
scaler=StandardScaler()
X_scale=scaler.fit_transform(X)

x_train, x_test, y_train, y_test = train_test_split(X_scale,y,test_size=0.2,stratify=y,random_state=42)
x_train,x_valid, y_train, y_valid = train_test_split(x_train,y_train,test_size=0.25,stratify=y_train,random_state=42)

print(x_train.shape)
print(x_valid.shape)
print(x_test.shape)
```

```
(4091, 95)
(1364, 95)
(1364, 95)
```

DimensionReduction

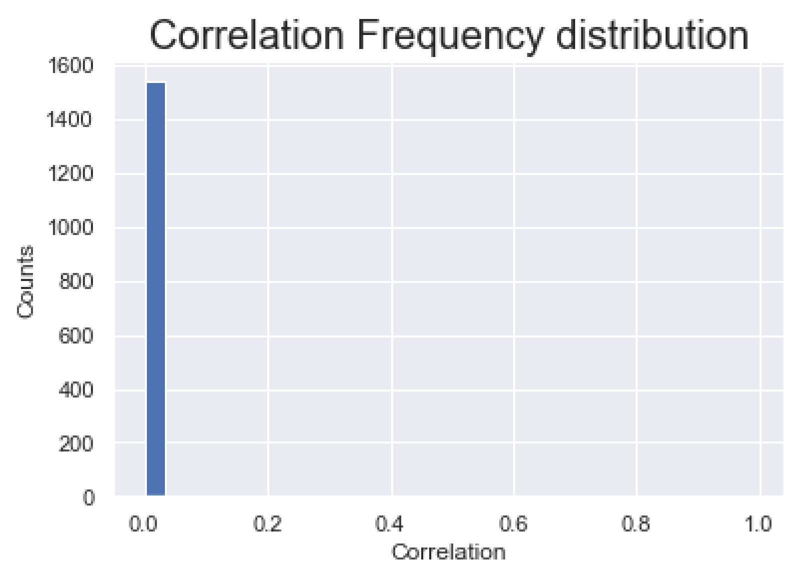
In [267]:
```
#56 principle components account for 99% explained data total variance
pca = PCA(n_components=56, svd_solver='full')

X_train = pca.fit_transform(x_train)
X_valid = pca.fit_transform(x_valid)
X_test = pca.fit_transform(x_test)

print(X_train.shape)
print(X_valid.shape)
print(X_test.shape)

plt.figure(figsize = (8,6))
plt.title("PCA")
plt.plot(pca.explained_variance_ratio_.cumsum())
plt.xlabel("Number of priciple components")
plt.ylabel("Cumulative Explanation")
plt.axhline(y=0.99, color='r', linestyle='--')
plt.show()
```

```
(4091, 56)
(1364, 56)
(1364, 56)
```



We can easily observe that after PCA, all data correlations are removed.

In [268]:
```
correlation_counts(pd.DataFrame(X_train))
```



Implementation

DNN

In [269]:
```
# Use Earlt stopping to eliminate useless epochs
model_stop = EarlyStopping(monitor='val_accuracy',
                           mode='max',
                           verbose=1,
                           patience=5,
                           restore_best_weights=True)
#I chose Dropout = 0.1 to decrease the probability of overfitting
model =  Sequential()
model.add(Dense(units=128,activation='relu'))
model.add(Dropout(0.50))
model.add(Dense(units=64,activation='relu'))
model.add(Dropout(0.50))
model.add(Dense(units=1,activation='sigmoid'))

# compile ANN
model.compile(loss='binary_crossentropy',
              optimizer='adam',
              metrics = ['accuracy'])
```

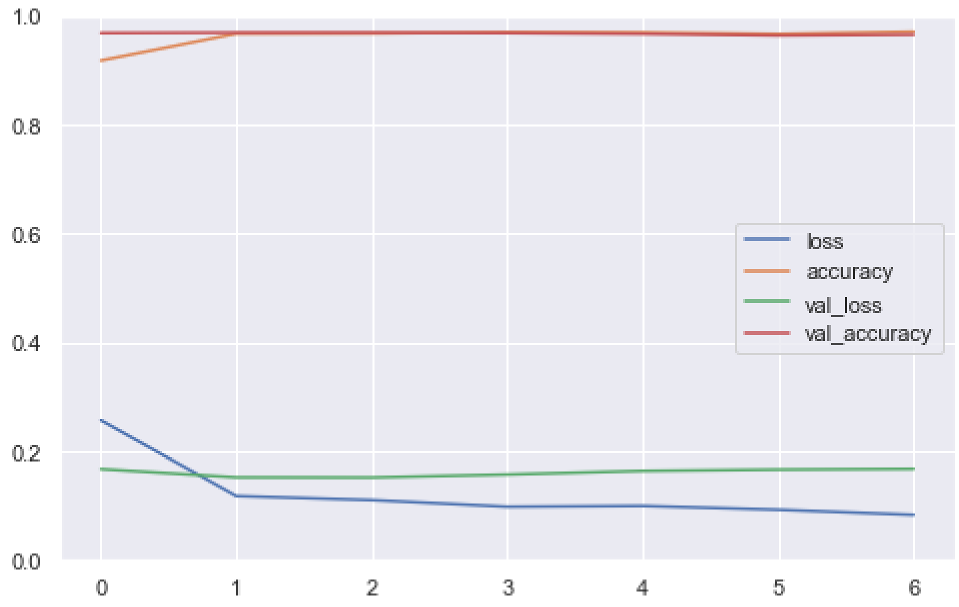
In [270]:
```
mymodel = model.fit(x_train, y_train, epochs=100,
                    validation_data=(x_test, y_test),
                    callbacks=[model_stop],
                   verbose = 0)
```

```
Restoring model weights from the end of the best epoch.
Epoch 00007: early stopping
```

In [271]:
```
model.summary()
```

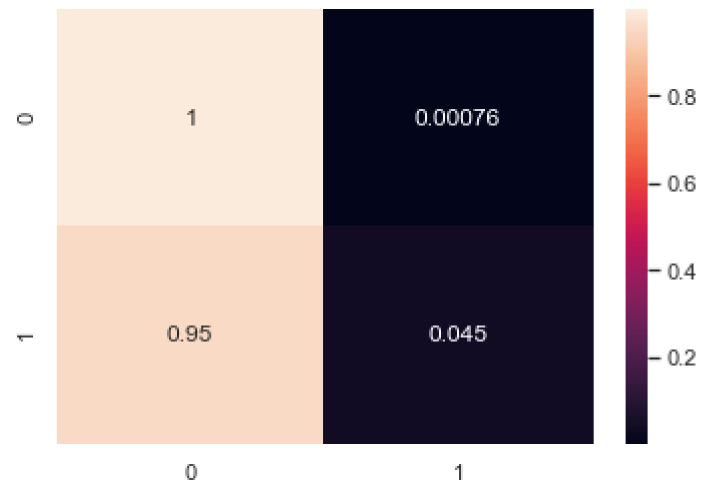
```
Model: "sequential_10"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
dense_30 (Dense)             (None, 128)               12288
_________________________________________________________________
dropout_20 (Dropout)         (None, 128)               0
_________________________________________________________________
dense_31 (Dense)             (None, 64)                8256
_________________________________________________________________
dropout_21 (Dropout)         (None, 64)                0
_________________________________________________________________
dense_32 (Dense)             (None, 1)                 65
=================================================================
Total params: 20,609
Trainable params: 20,609
Non-trainable params: 0
_________________________________________________________________
```

In [272]:
```
#This part of codes is from our lecture
pd.DataFrame(mymodel.history).plot(figsize=(8, 5))
plt.grid(True)
plt.gca().set_ylim(0, 1)
plt.show()
```

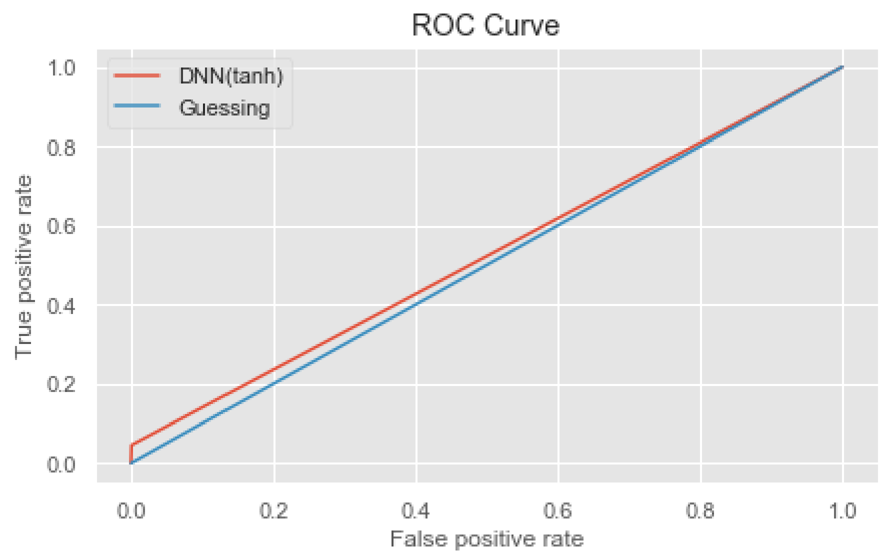


In [273]:
```
y_pred = model.predict(x_test)
y_pred = (y_pred > 0.5)
print(classification_report(y_test, y_pred))
sns.heatmap(confusion_matrix(y_test,y_pred,normalize='true'), annot=True)
print("We have f1-score : ",f1_score(y_test, y_pred))
```

```
              precision    recall  f1-score   support

           0       0.97      1.00      0.98      1320
           1       0.67      0.05      0.09        44

    accuracy                           0.97      1364
   macro avg       0.82      0.52      0.53      1364
weighted avg       0.96      0.97      0.95      1364

We have f1-score :  0.08510638297872342
```



In [274]:
```
fpr, tpr, _ = roc_curve(y_test, y_pred)
with plt.style.context('ggplot'):
    plt.figure(figsize=(7,4))
    plt.plot(fpr, tpr, [0,1], [0,1])
    plt.grid(True)
    plt.title('ROC Curve')
    plt.xlabel('False positive rate')
    plt.ylabel('True positive rate')
    plt.legend(['DNN(tanh)', 'Guessing'])
```

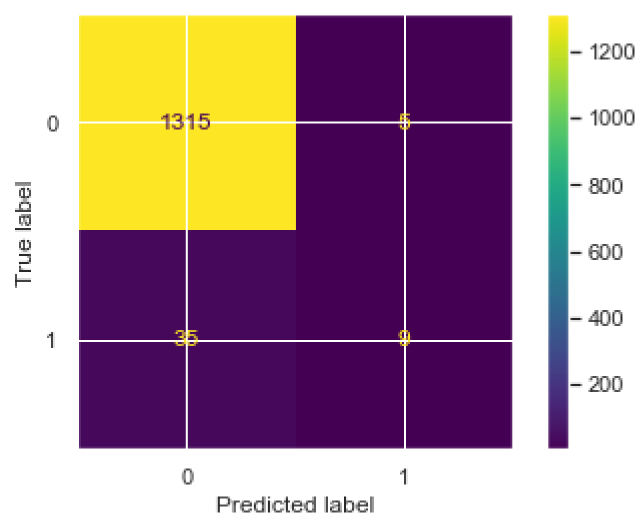


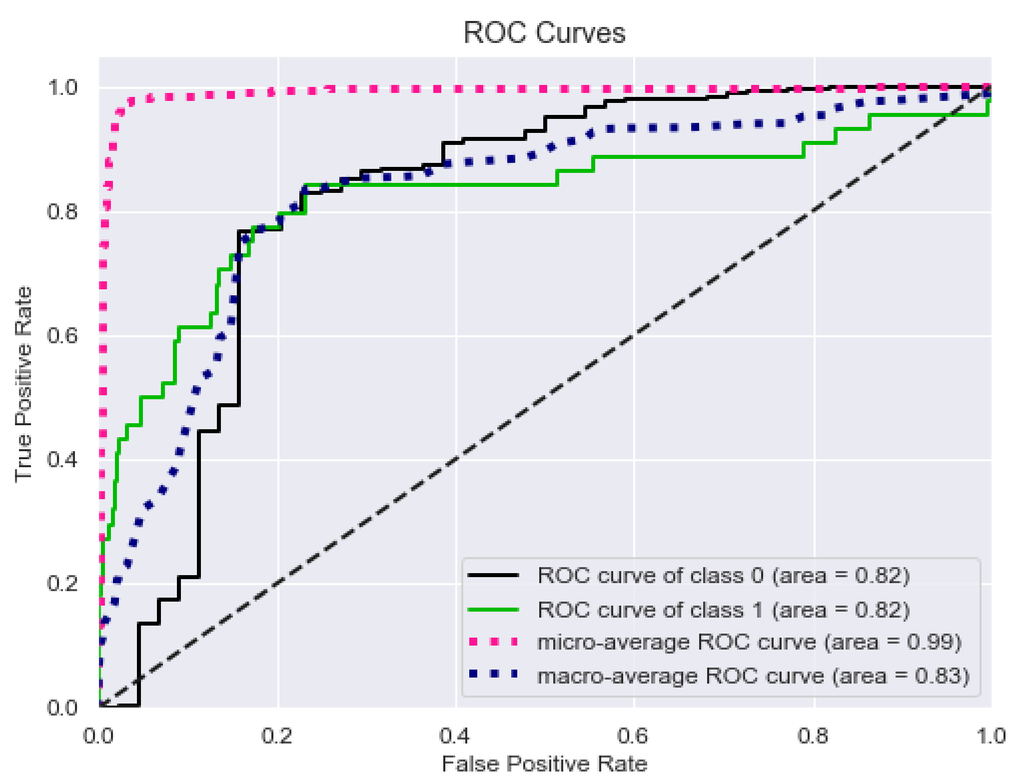
LogisticRegression

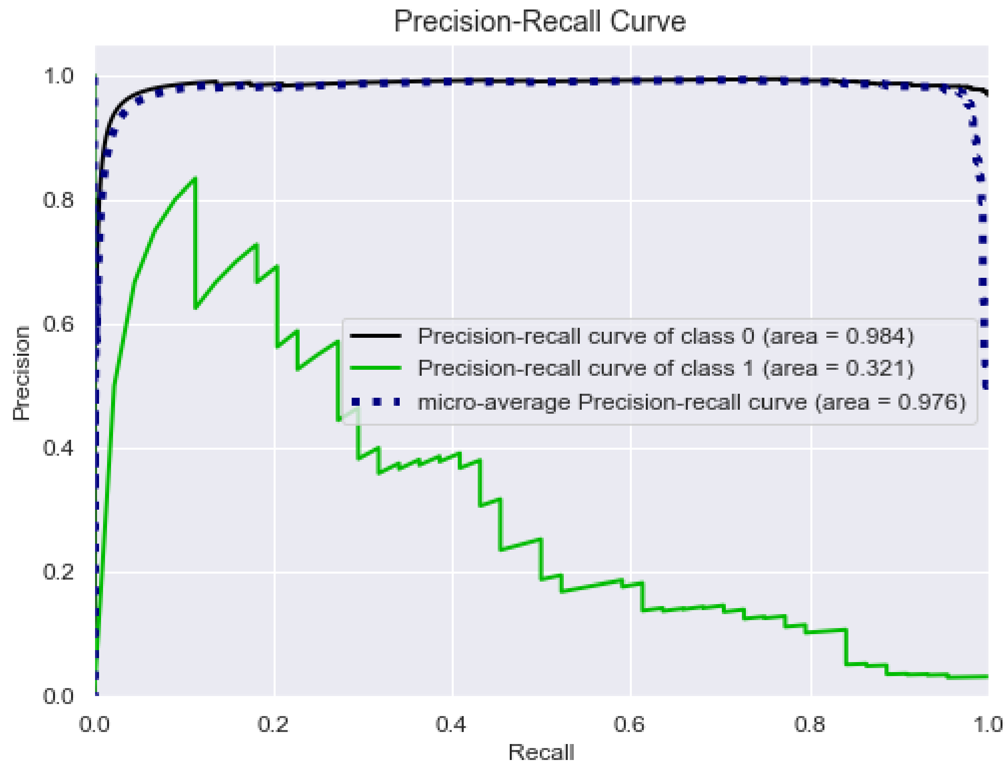
In [228]:

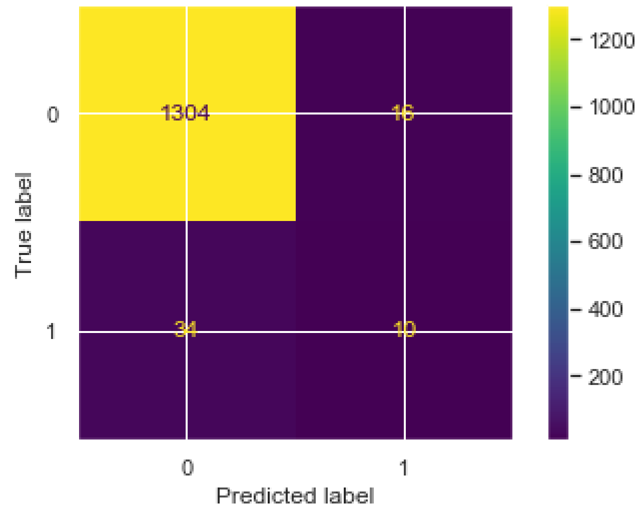
```
print('='*100)
print("Use lr to evaluate on the validation set")
lr_model = LogisticRegression()
model_eval(lr_model,x_train,y_train,x_valid,y_valid)
print('='*100)
print("Use lr to evaluate on the test set")
model_eval(lr_model,x_train,y_train,x_test,y_test)
```

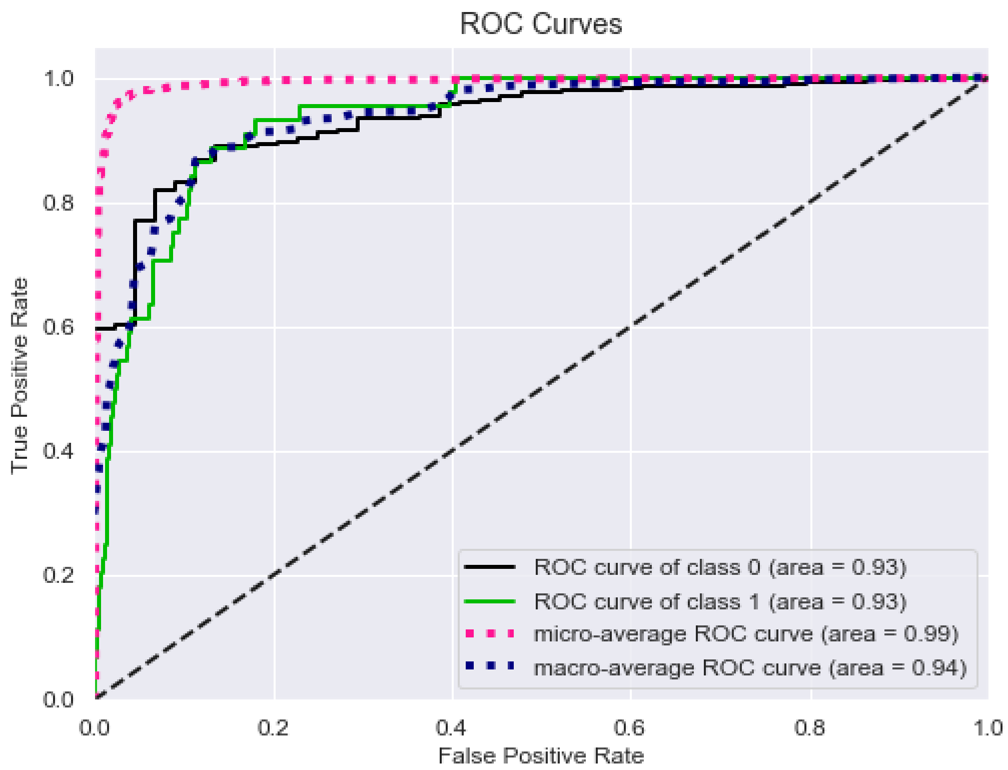
```
==========================================================================================
Use lr to evaluate on the validation set
auc: 0.8194559228650139
accuracy score: 0.9706744868035191
==========================================================================================
******************************************************************************************
precision_micro: 0.9706744868035191     recall_micro: 0.9706744868035191       f1_micro: 0.9706744868035191
precision_macro: 0.8084656084656086     recall_macro: 0.6003787878787878       f1_macro: 0.6476817770889836
******************************************************************************************
==========================================================================================
Classification Report:
              precision    recall  f1-score   support

           0      0.974     0.996     0.985      1320
           1      0.643     0.205     0.310        44

    accuracy                          0.971      1364
   macro avg      0.808     0.600     0.648      1364
weighted avg      0.963     0.971     0.963      1364

==========================================================================================
==========================================================================================
Use lr to evaluate on the test set
auc: 0.934263085399449
accuracy score: 0.9633431085043989
==========================================================================================
******************************************************************************************
precision_micro: 0.9633431085043989     recall_micro: 0.9633431085043989       f1_micro: 0.9633431085043989
precision_macro: 0.6796021616649419     recall_macro: 0.6075757575757575       f1_macro: 0.6334515747608298
******************************************************************************************
==========================================================================================
Classification Report:
              precision    recall  f1-score   support

           0      0.975     0.988     0.981      1320
           1      0.385     0.227     0.286        44

    accuracy                          0.963      1364
   macro avg      0.680     0.608     0.633      1364
weighted avg      0.956     0.963     0.959      1364

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

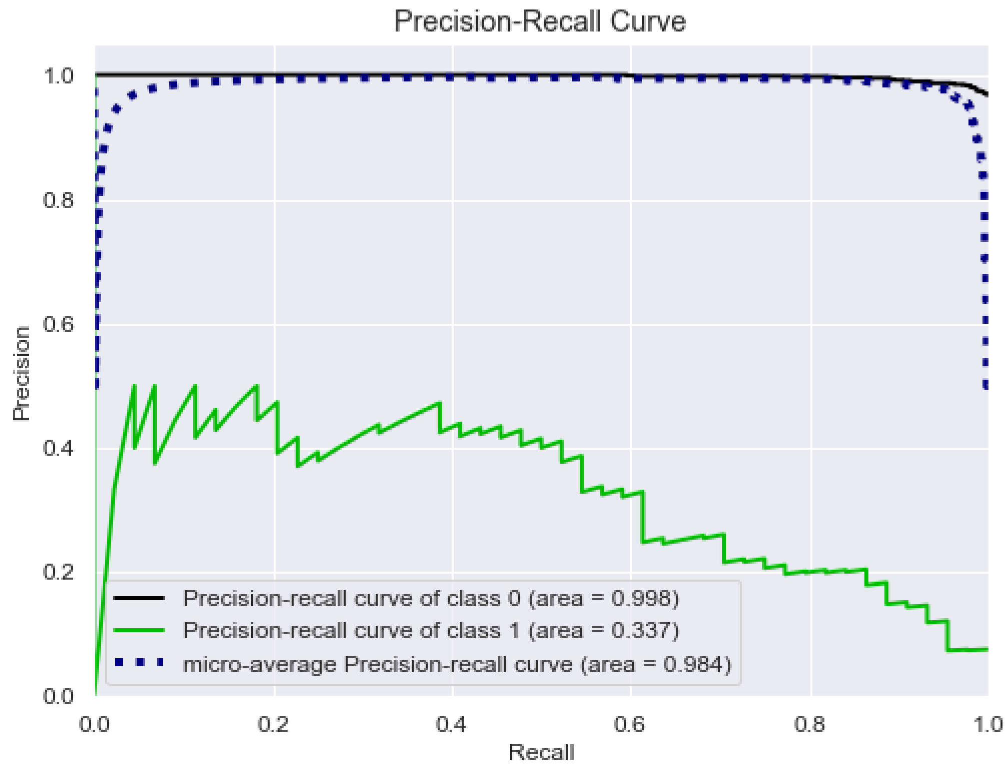





Precision-Recall Curve
Precision
Recall
Precision-recall curve of class 0 (area = 0.984)
Precision-recall curve of class 1 (area = 0.321)
micro-average Precision-recall curve (area = 0.976)


True label
Predicted label
1304
16
34
10


ROC Curves
True Positive Rate
False Positive Rate
ROC curve of class 0 (area = 0.93)
ROC curve of class 1 (area = 0.93)
micro-average ROC curve (area = 0.99)
macro-average ROC curve (area = 0.94)

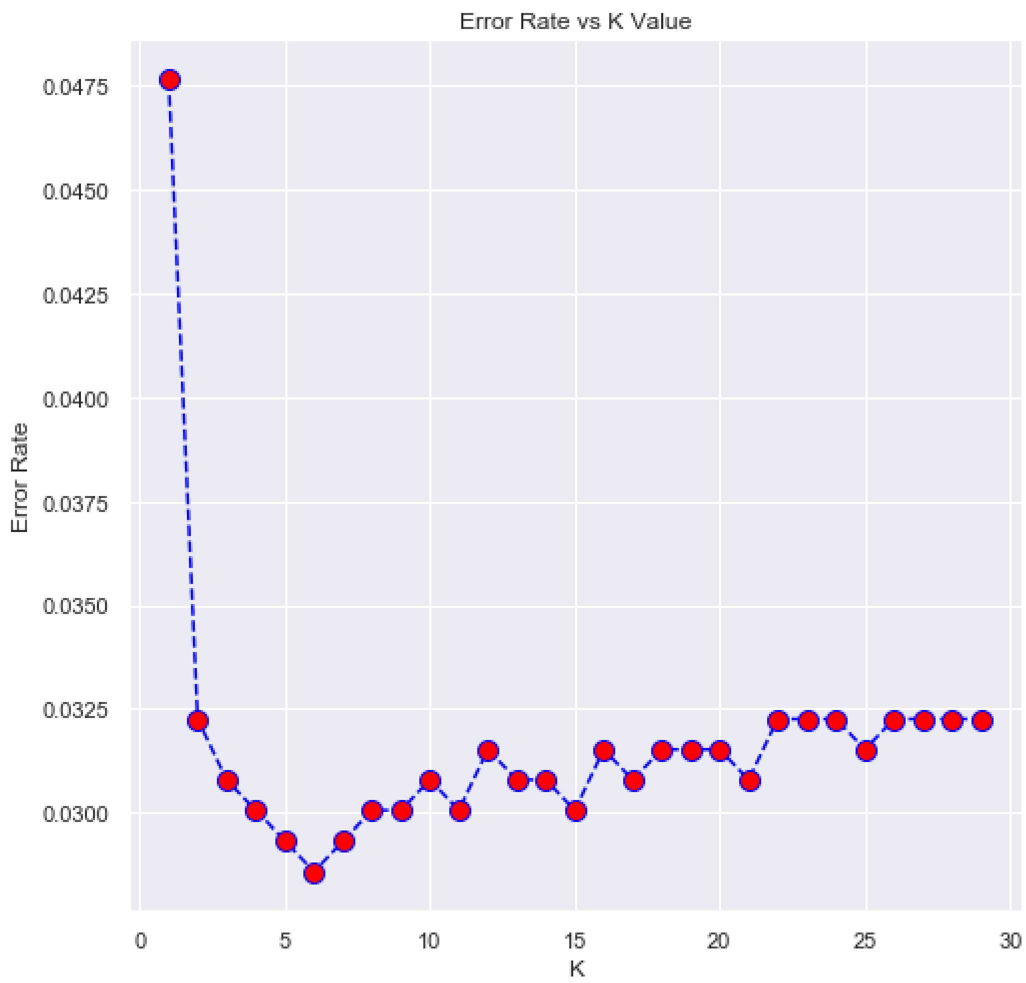

Precision-Recall Curve
Precision
Recall
Precision-recall curve of class 0 (area = 0.998)
Precision-recall curve of class 1 (area = 0.337)
micro-average Precision-recall curve (area = 0.984)

KNN

In [229]:
```
error = []

for i in range(1,30):
    knn = KNeighborsClassifier(n_neighbors = i)
    knn.fit(x_train, y_train)
    pred_knn = knn.predict(x_test)
    error.append(np.mean(pred_knn != y_test))
```

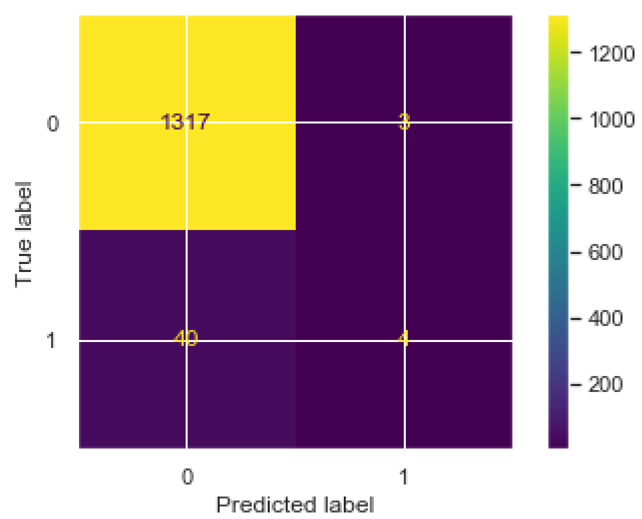
In [230]:
```
plt.figure(figsize = (8,8))
plt.plot(range(1,30), error,
         color = 'blue',
         linestyle = 'dashed',
         marker = 'o',
         markerfacecolor = 'red',
         markersize = 10);
plt.title('Error Rate vs K Value')
plt.xlabel('K')
plt.ylabel('Error Rate')
```

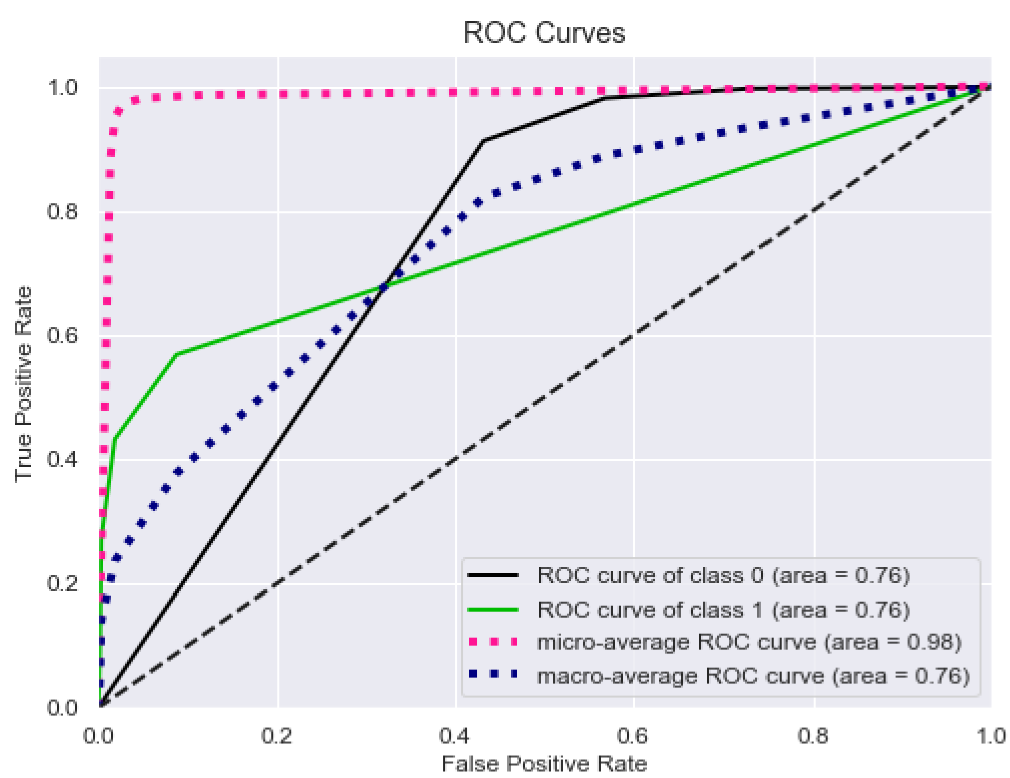
Out[230]:
```
Text(0, 0.5, 'Error Rate')
```

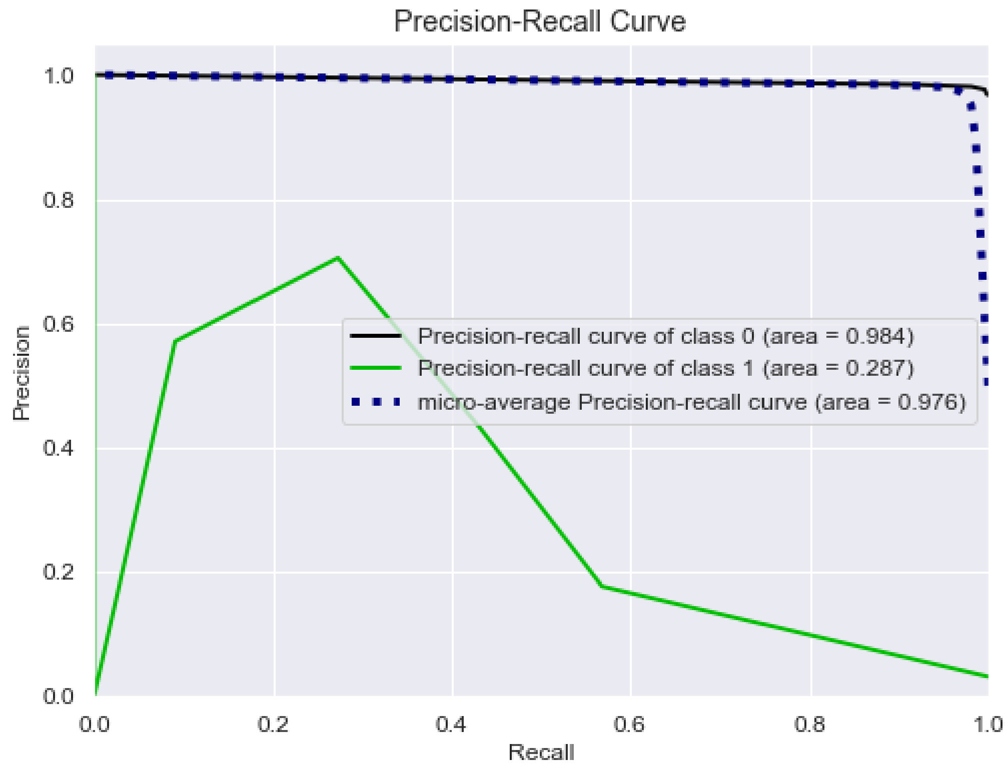


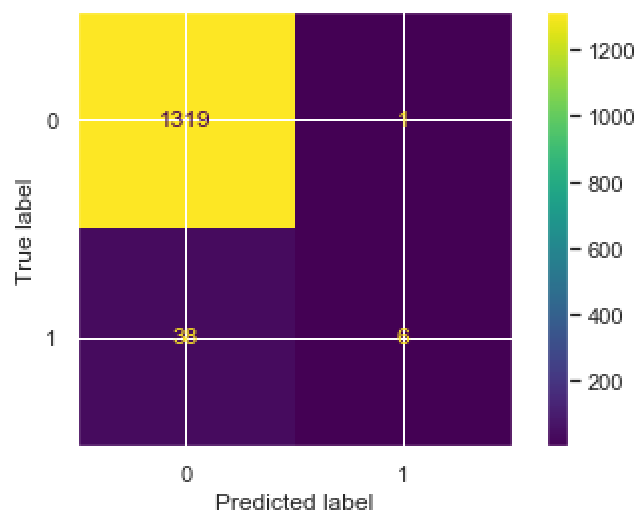
In [231]:
```
knn_model = KNeighborsClassifier(n_neighbors = 6)
print('='*100)
print("Use knn to evaluate on the validation set")
model_eval(knn_model,x_train,y_train,x_valid,y_valid)
print('='*100)
print("Use knn to evaluate on the test set")
model_eval(knn_model,x_train,y_train,x_test,y_test)
```

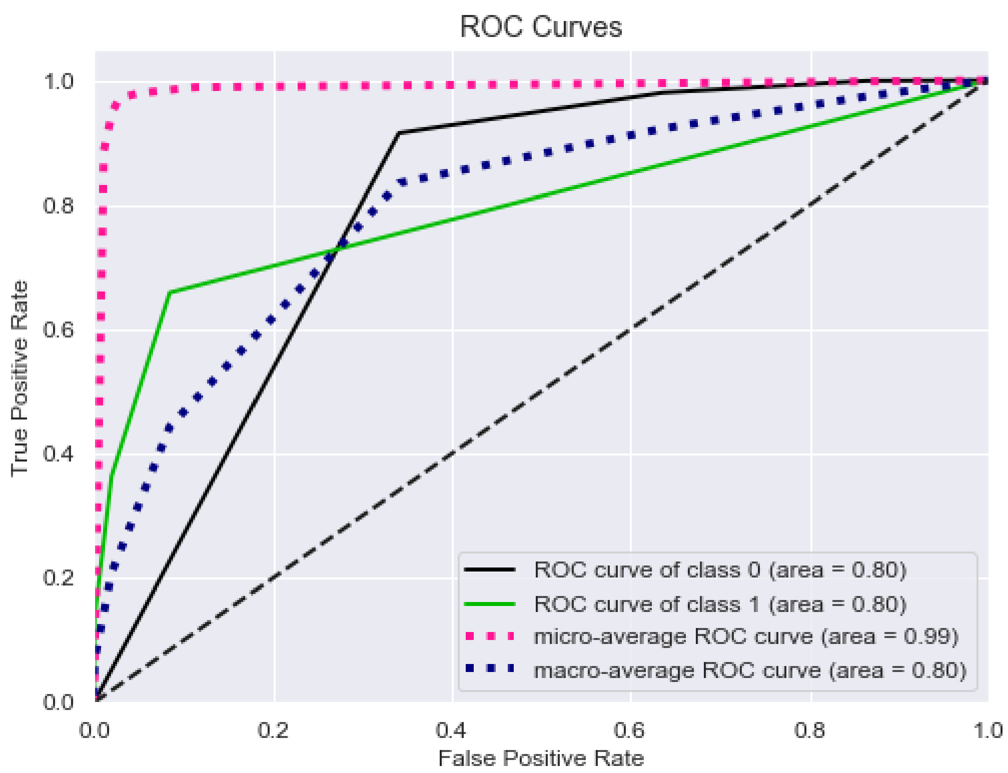
```
====================================================================================================
Use knn to evaluate on the validation set
auc: 0.7553374655647384
accuracy score: 0.968475073313783
====================================================================================================
****************************************************************************************************
precision_micro: 0.968475073313783      recall_micro: 0.968475073313783 f1_micro: 0.968475073313783
precision_macro: 0.7709758921991788     recall_macro: 0.5443181818181818        f1_macro: 0.5703999941403533
****************************************************************************************************
====================================================================================================
Classification Report:
               precision    recall  f1-score   support

           0      0.971     0.998     0.984      1320
           1      0.571     0.091     0.157        44

    accuracy                          0.968      1364
   macro avg      0.771     0.544     0.570      1364
weighted avg      0.958     0.968     0.957      1364

====================================================================================================
====================================================================================================
Use knn to evaluate on the test set
auc: 0.7972710055096419
accuracy score: 0.9714076246334311
====================================================================================================
****************************************************************************************************
precision_micro: 0.9714076246334311     recall_micro: 0.9714076246334311        f1_micro: 0.9714076246334311
precision_macro: 0.914569954732077      recall_macro: 0.5678030303030304        f1_macro: 0.6103627853831111
****************************************************************************************************
====================================================================================================
Classification Report:
               precision    recall  f1-score   support

           0      0.972     0.999     0.985      1320
           1      0.857     0.136     0.235        44

    accuracy                          0.971      1364
   macro avg      0.915     0.568     0.610      1364
weighted avg      0.968     0.971     0.961      1364

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

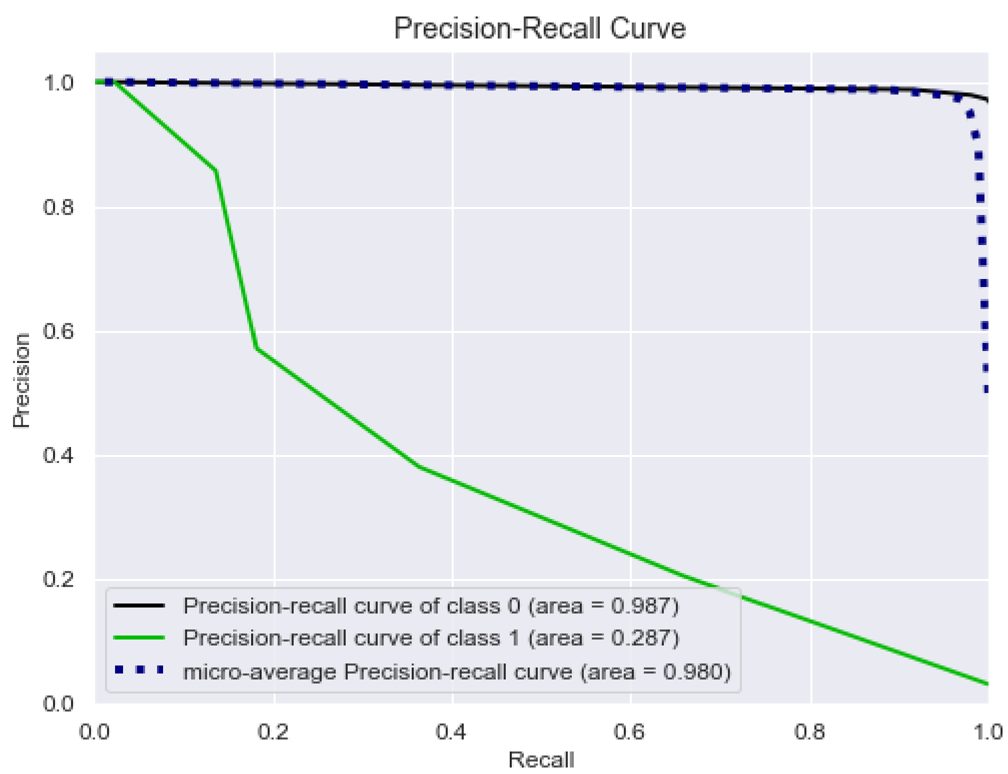





Precision-Recall Curve
Precision
Recall
Precision-recall curve of class 0 (area = 0.984)
Precision-recall curve of class 1 (area = 0.287)
micro-average Precision-recall curve (area = 0.976)


1319
1
38
6
True label
Predicted label
0
1
1200
1000
800
600
400
200


ROC Curves
True Positive Rate
False Positive Rate
ROC curve of class 0 (area = 0.80)
ROC curve of class 1 (area = 0.80)
micro-average ROC curve (area = 0.99)
macro-average ROC curve (area = 0.80)

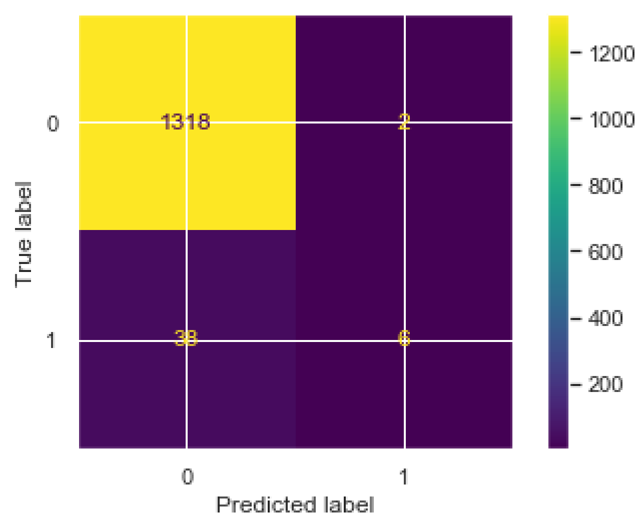

Precision-Recall Curve
Precision
Recall
Precision-recall curve of class 0 (area = 0.987)
Precision-recall curve of class 1 (area = 0.287)
micro-average Precision-recall curve (area = 0.980)

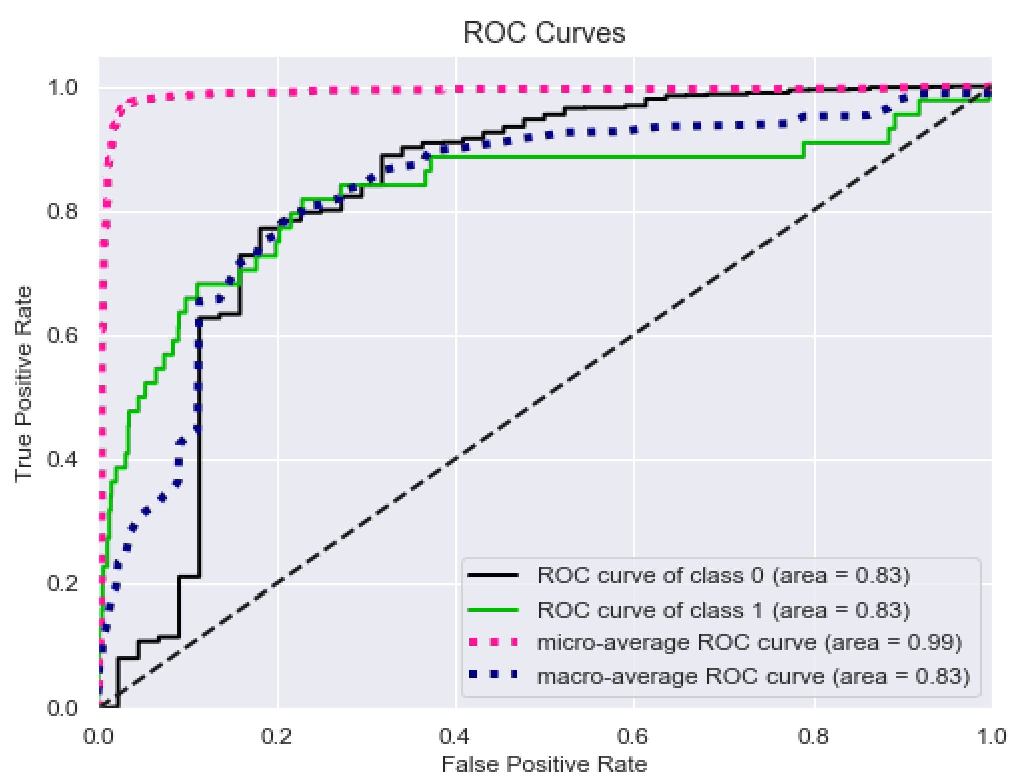
SVM

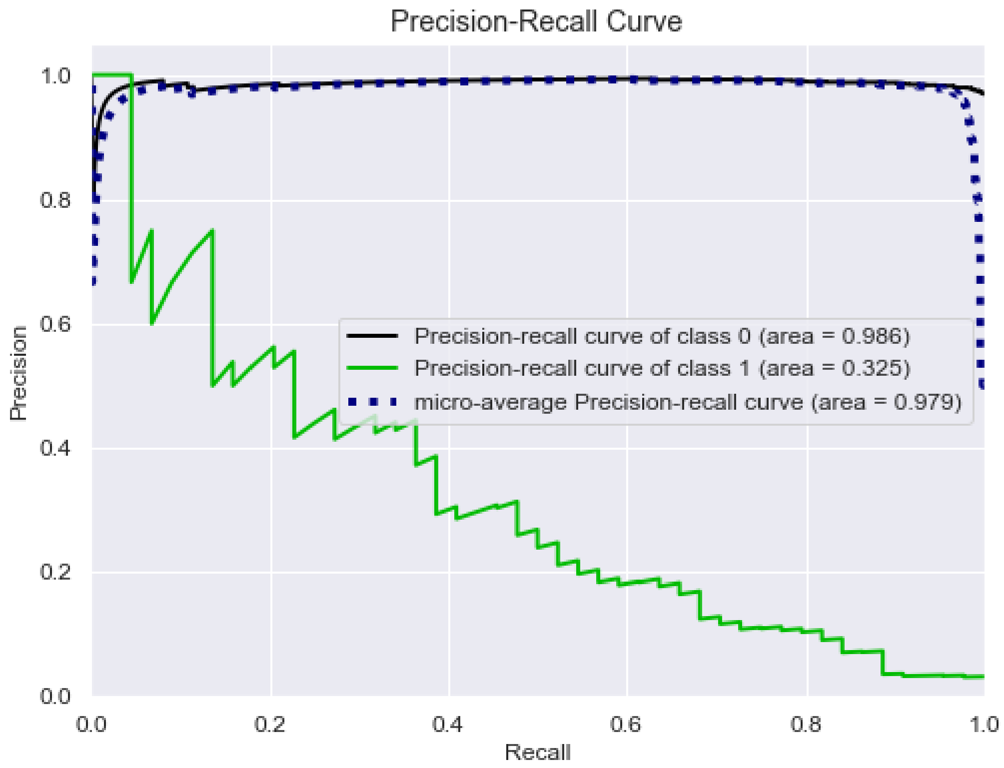
In [203]:
```
#params = [{'kernel': ['rbf'], 'gamma': [1e-3, 1e-4],
                    #'C': [1, 10, 100, 1000]},
                    #{'kernel': ['linear'], 'C': [1, 10, 100, 1000]}]


#svm = SVC(probability = True)
#svm = GridSearchCV(svm, params)
```

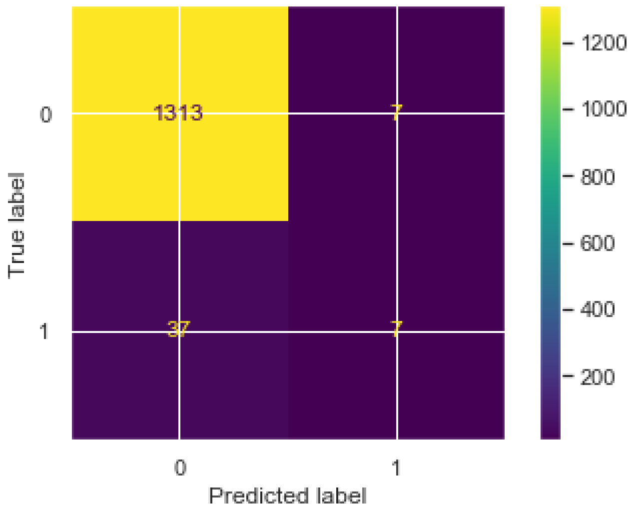
In [279]:
```
svm = SVC(probability = True, kernel = 'linear',C = 1, gamma = 1e-3)

print('='*100)
print("Use SVM to evaluate on the validation set")
model_eval(svm,x_train,y_train,x_valid,y_valid)
print('='*100)
print("Use svm to evaluate on the test set")
model_eval(svm,x_train,y_train,x_test,y_test)
```

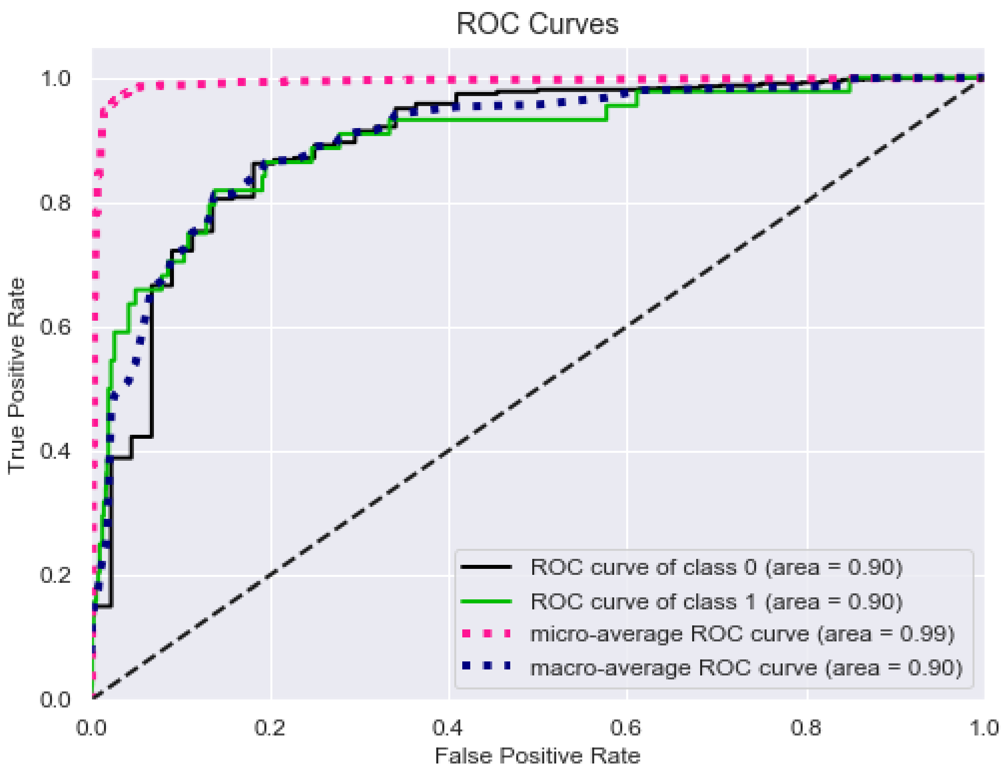
```
====================================================================================================
Use SVM to evaluate on the validation set
auc: 0.8261707988980715
accuracy score: 0.9706744868035191
====================================================================================================
****************************************************************************************************
precision_micro: 0.9706744868035191      recall_micro: 0.9706744868035191        f1_micro: 0.9706744868035191
precision_macro: 0.8609882005899705      recall_macro: 0.5674242424242424        f1_macro: 0.6079107738300563
****************************************************************************************************
====================================================================================================
Classification Report:
               precision    recall  f1-score   support

           0       0.972     0.998     0.985      1320
           1       0.750     0.136     0.231        44

    accuracy                           0.971      1364
   macro avg       0.861     0.567     0.608      1364
weighted avg       0.965     0.971     0.961      1364

====================================================================================================
====================================================================================================
Use svm to evaluate on the test set
auc: 0.896926652892562
accuracy score: 0.967741935483871
====================================================================================================
****************************************************************************************************
precision_micro: 0.967741935483871      recall_micro: 0.967741935483871 f1_micro: 0.967741935483871
precision_macro: 0.7362962962962962      recall_macro: 0.5768939393939394        f1_macro: 0.612449954797882
****************************************************************************************************
====================================================================================================
Classification Report:
               precision    recall  f1-score   support

           0       0.973     0.995     0.984      1320
           1       0.500     0.159     0.241        44

    accuracy                           0.968      1364
   macro avg       0.736     0.577     0.612      1364
weighted avg       0.957     0.968     0.960      1364

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

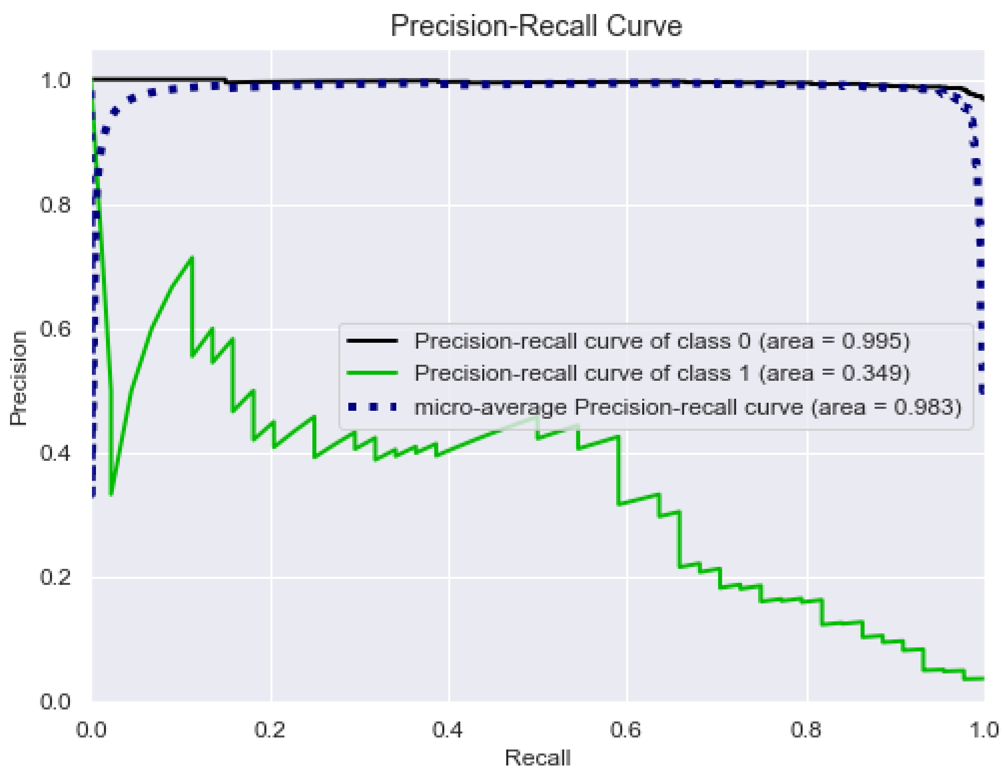





Precision-Recall Curve
Precision
Recall
Precision-recall curve of class 0 (area = 0.986)
Precision-recall curve of class 1 (area = 0.325)
micro-average Precision-recall curve (area = 0.979)


True label
Predicted label
1313
7
37
7


ROC Curves
True Positive Rate
False Positive Rate
ROC curve of class 0 (area = 0.90)
ROC curve of class 1 (area = 0.90)
micro-average ROC curve (area = 0.99)
macro-average ROC curve (area = 0.90)

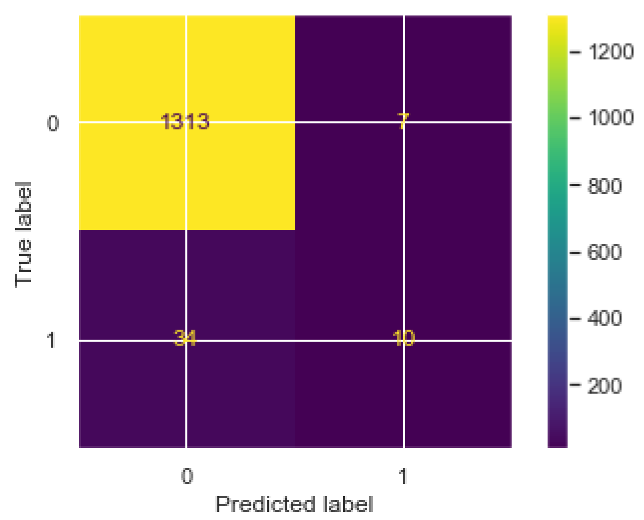

Precision-Recall Curve
Precision
Recall
Precision-recall curve of class 0 (area = 0.995)
Precision-recall curve of class 1 (area = 0.349)
micro-average Precision-recall curve (area = 0.983)

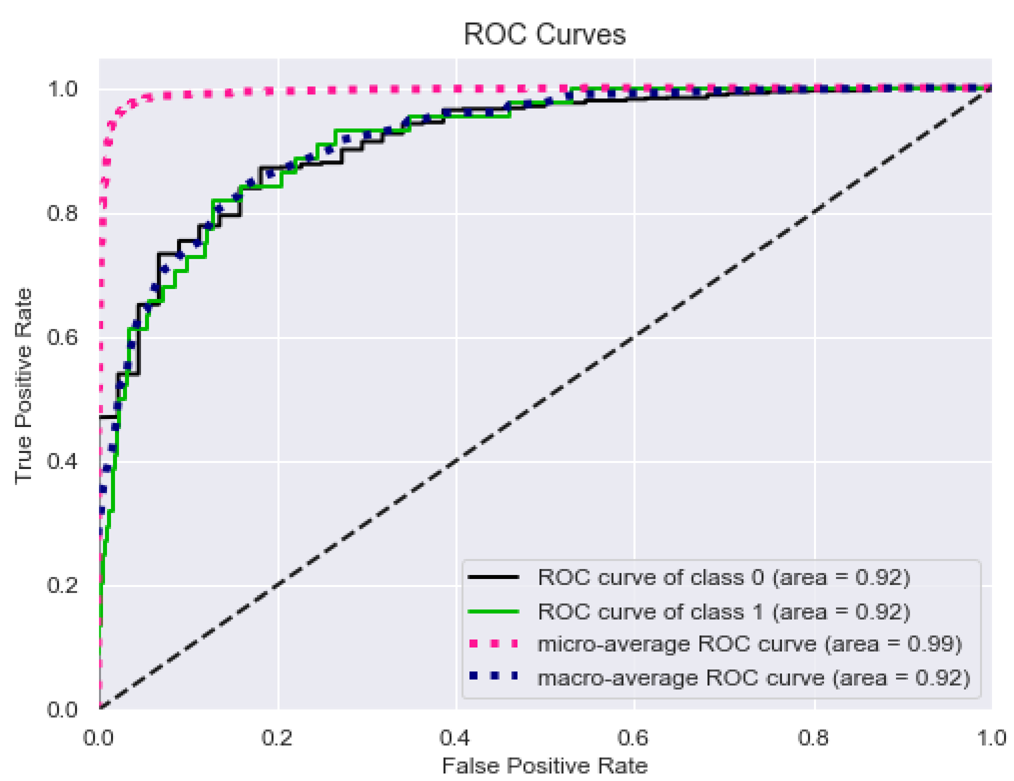
XGBoost

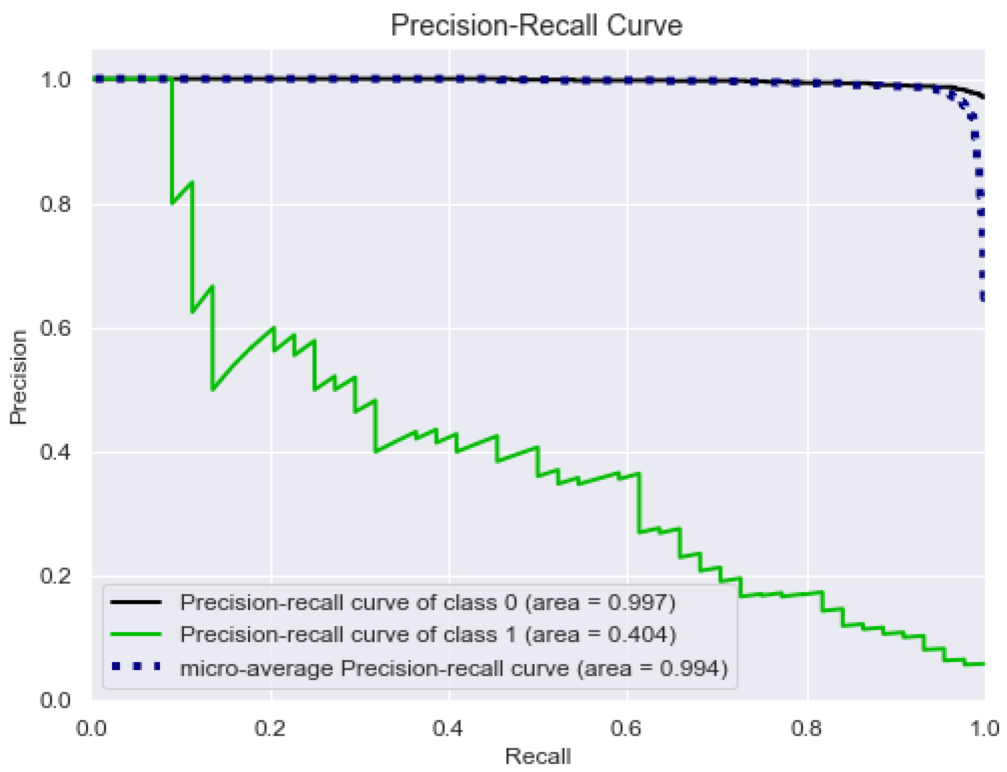
In [283]:

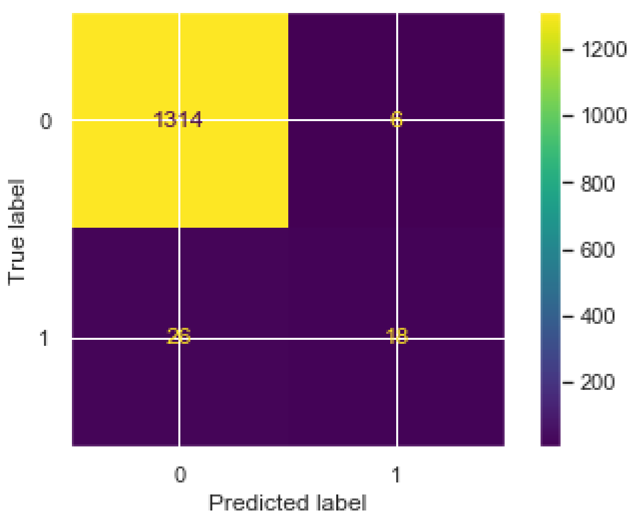
```
xgb = XGBClassifier(n_estimators = 1000)
print('='*100)
print("Use XGBoost to evaluate on the validation set")
model_eval(xgb,x_train,y_train,x_valid,y_valid)
print('='*100)
print("Use XGBoost to evaluate on the test set")
model_eval(xgb,x_train,y_train,x_test,y_test)
```

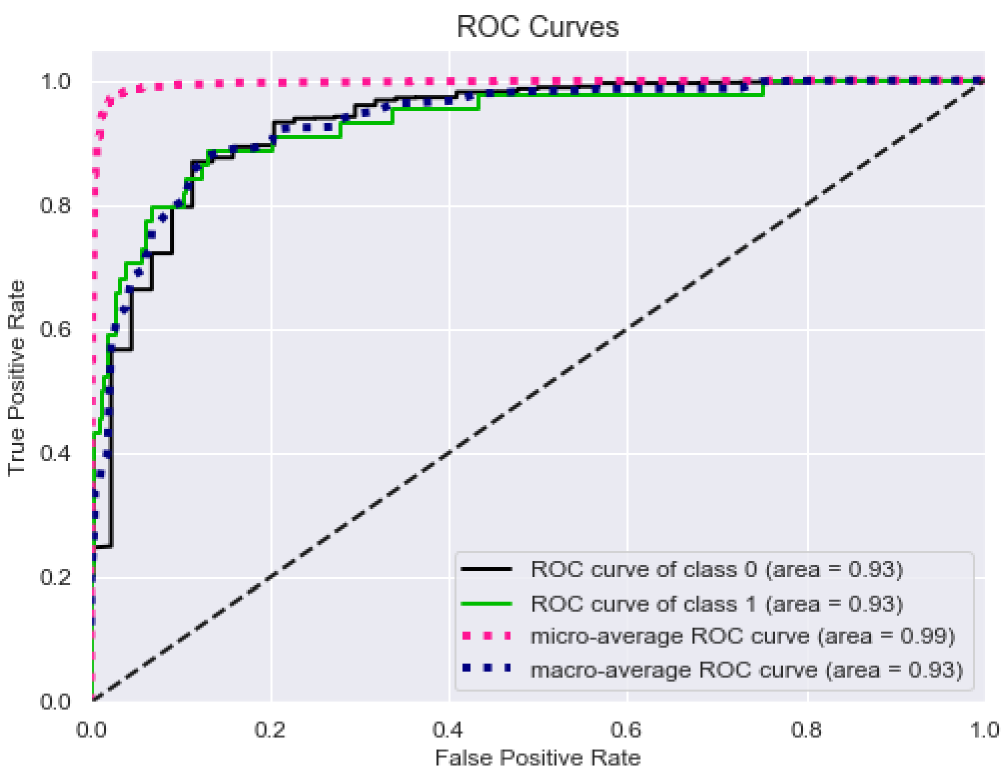
```
====================================================================================================
Use XGBoost to evaluate on the validation set
[23:54:31] WARNING: C:/Users/Administrator/workspace/xgboost-win64_release_1.3.0/src/learner.cc:1061: Starting in XGBoost 1.3.0, the default evaluation metric used with the objective 'binary:logistic' was changed from 'error' to 'logloss'. Explicitly set eval_metric if you'd like to restore the old behavior.
auc: 0.9162190082644628
accuracy score: 0.9699413489736071
====================================================================================================
****************************************************************************************************
precision_micro: 0.9699413489736071     recall_micro: 0.9699413489736071        f1_micro: 0.9699413489736071
precision_macro: 0.7814970086029958     recall_macro: 0.6109848484848485        f1_macro: 0.6562478870469061
****************************************************************************************************
====================================================================================================
Classification Report:
               precision    recall  f1-score   support

           0      0.975     0.995     0.985      1320
           1      0.588     0.227     0.328        44

    accuracy                          0.970      1364
   macro avg      0.781     0.611     0.656      1364
weighted avg      0.962     0.970     0.963      1364

====================================================================================================
====================================================================================================
Use XGBoost to evaluate on the test set
[23:54:35] WARNING: C:/Users/Administrator/workspace/xgboost-win64_release_1.3.0/src/learner.cc:1061: Starting in XGBoost 1.3.0, the default evaluation metric used with the objective 'binary:logistic' was changed from 'error' to 'logloss'. Explicitly set eval_metric if you'd like to restore the old behavior.
auc: 0.9313705234159779
accuracy score: 0.9765395894428153
====================================================================================================
****************************************************************************************************
precision_micro: 0.9765395894428153     recall_micro: 0.9765395894428153        f1_micro: 0.9765395894428153
precision_macro: 0.8652985074626866     recall_macro: 0.7022727272727273        f1_macro: 0.7586908447589562
****************************************************************************************************
====================================================================================================
Classification Report:
               precision    recall  f1-score   support

           0      0.981     0.995     0.988      1320
           1      0.750     0.409     0.529        44

    accuracy                          0.977      1364
   macro avg      0.865     0.702     0.759      1364
weighted avg      0.973     0.977     0.973      1364

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

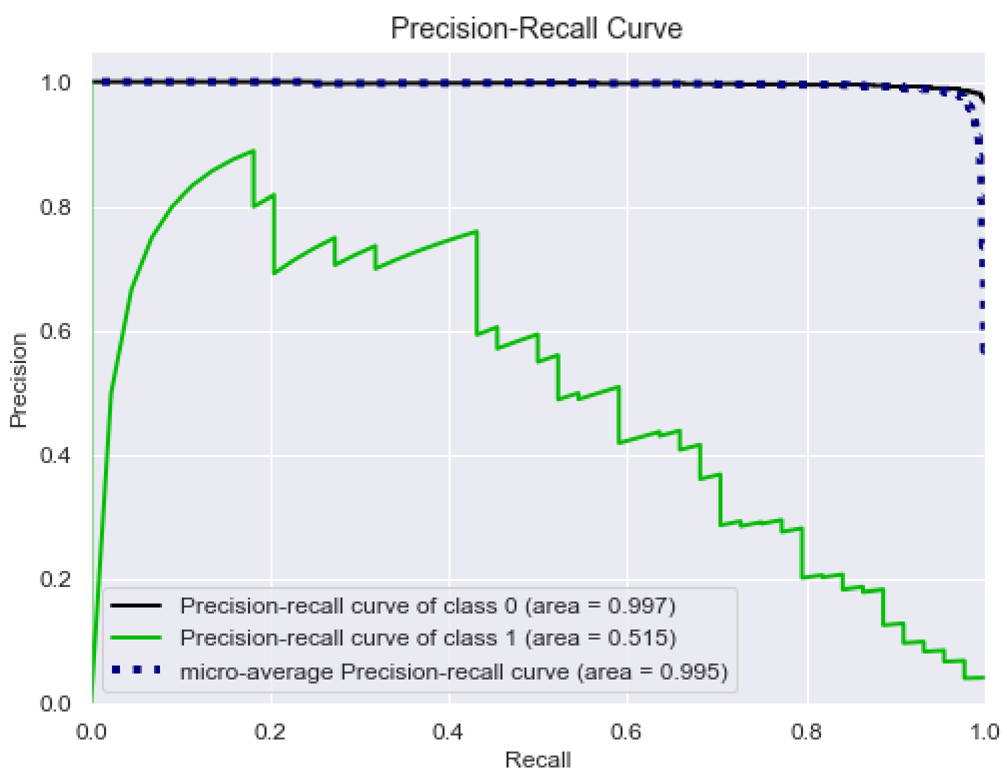





Precision-Recall Curve
Precision
Recall
Precision-recall curve of class 0 (area = 0.997)
Precision-recall curve of class 1 (area = 0.404)
micro-average Precision-recall curve (area = 0.994)


1314
6
26
18
True label
Predicted label


ROC Curves
True Positive Rate
False Positive Rate
ROC curve of class 0 (area = 0.93)
ROC curve of class 1 (area = 0.93)
micro-average ROC curve (area = 0.99)
macro-average ROC curve (area = 0.93)

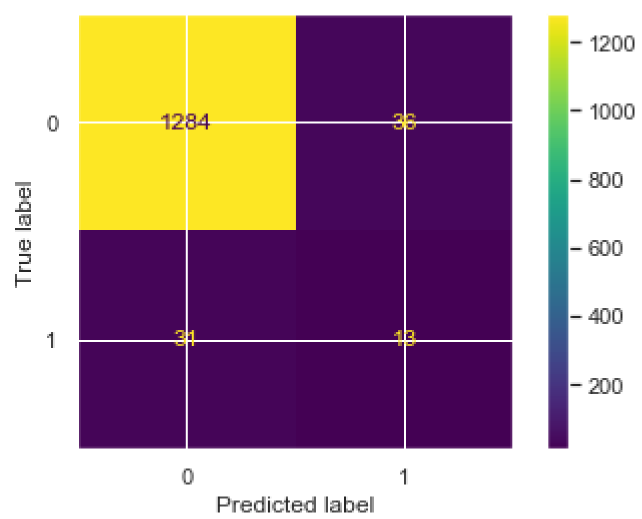

Precision-Recall Curve
Precision
Recall
Precision-recall curve of class 0 (area = 0.997)
Precision-recall curve of class 1 (area = 0.515)
micro-average Precision-recall curve (area = 0.995)

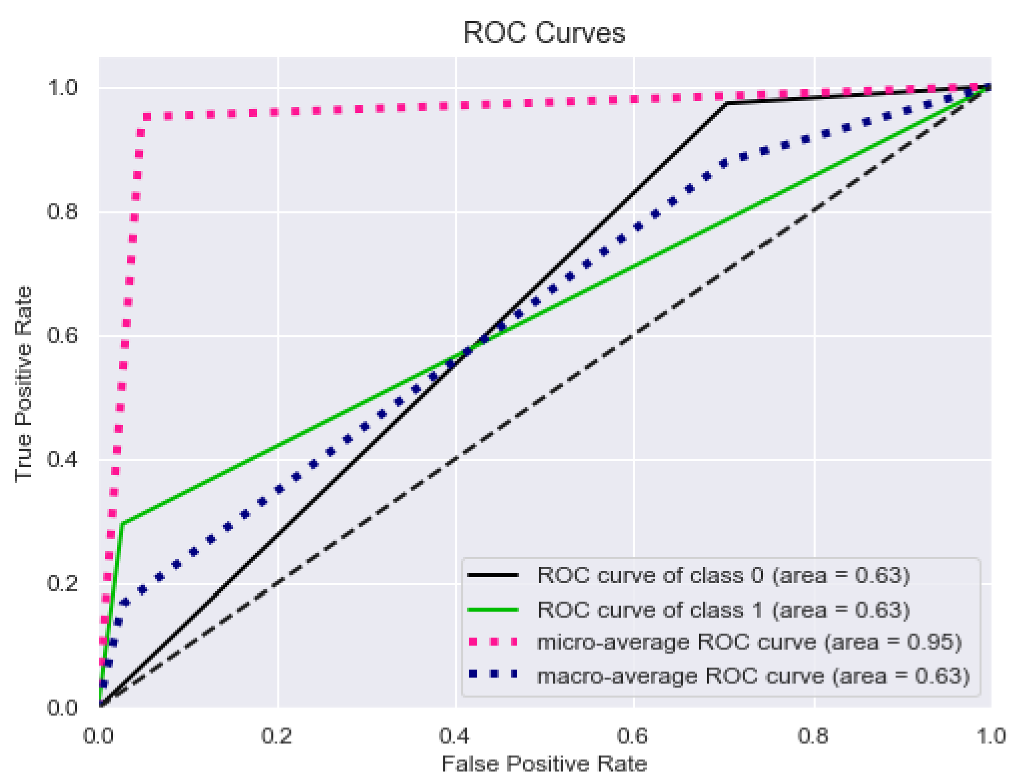
DecisionTree

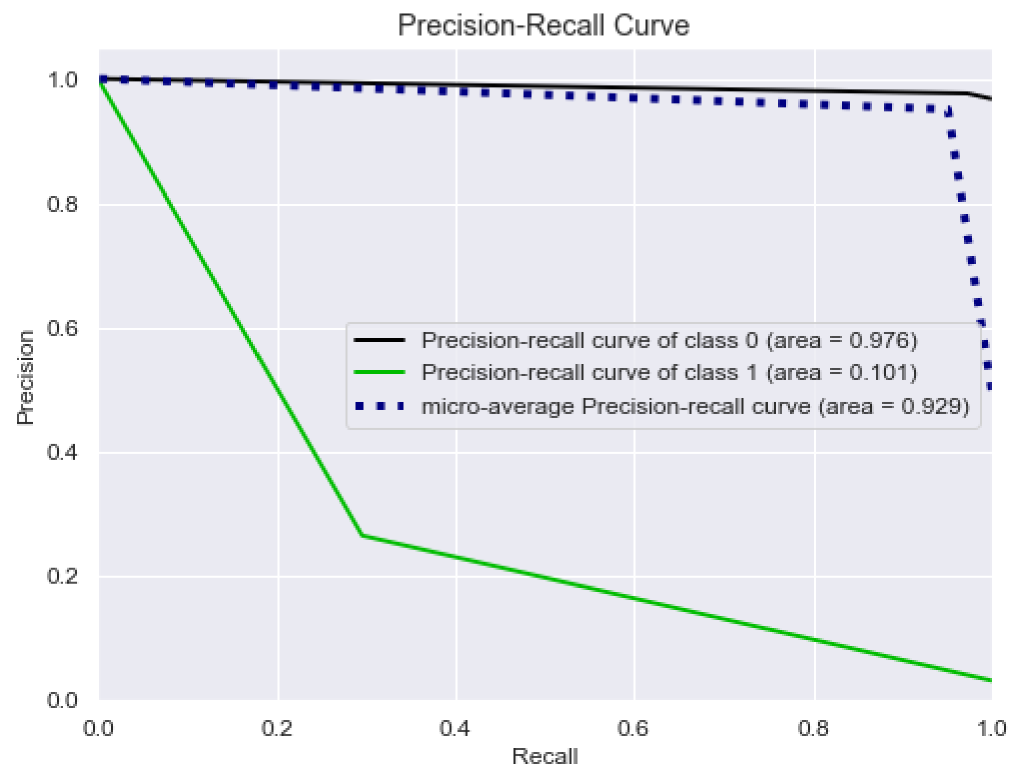
In [284]:

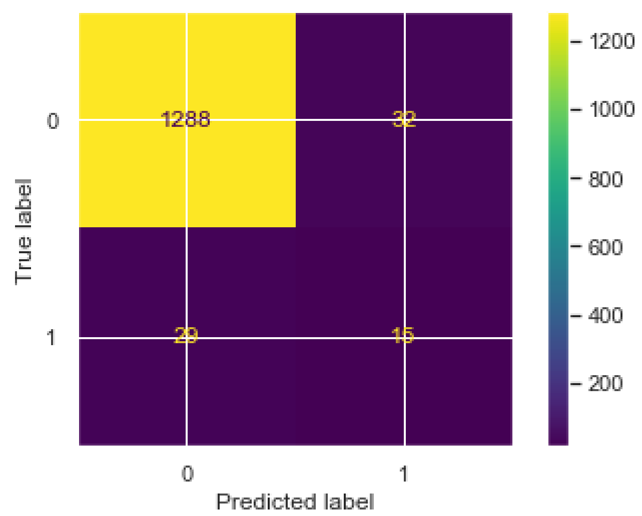
```
DTC = DecisionTreeClassifier()
print('='*100)
print("Use DecisionTree to evaluate on the validation set")
model_eval(DTC,x_train,y_train,x_valid,y_valid)
print('='*100)
print("Use DecisionTree to evaluate on the test set")
model_eval(DTC,x_train,y_train,x_test,y_test)
```

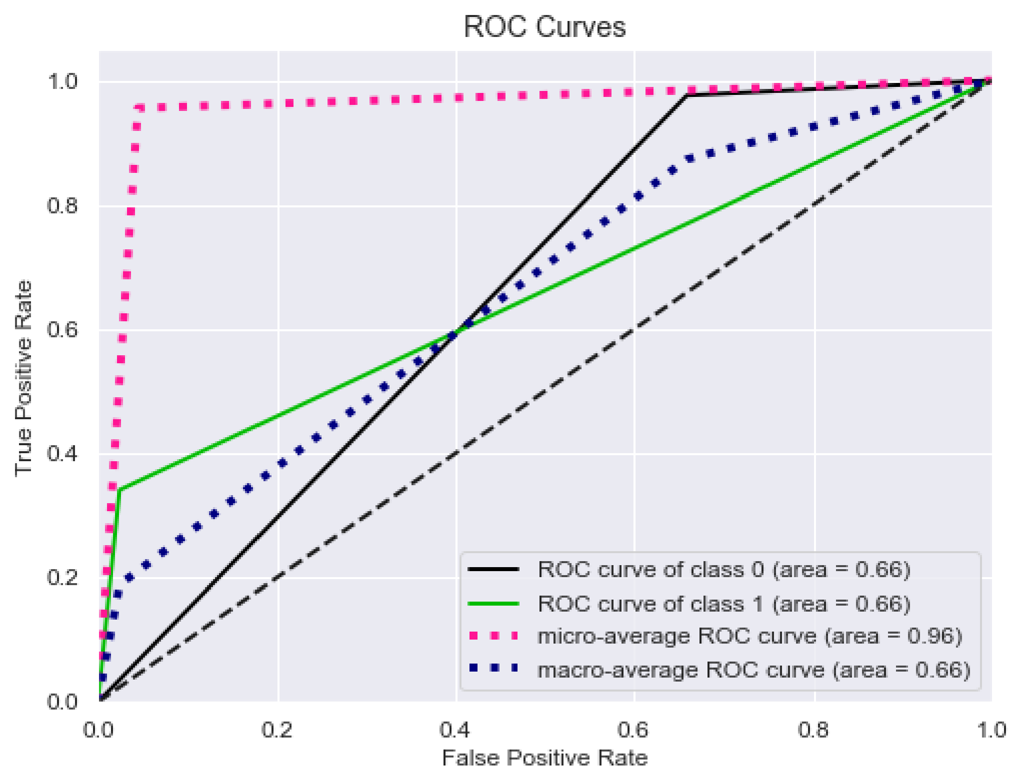
```
====================================================================================================
Use DecisionTree to evaluate on the validation set
auc: 0.634090909090909
accuracy score: 0.9508797653958945
====================================================================================================
****************************************************************************************************
precision_micro: 0.9508797653958945     recall_micro: 0.9508797653958945       f1_micro: 0.9508797653958945
precision_macro: 0.6208659889811438     recall_macro: 0.6340909090909091       f1_macro: 0.6270714737507906
****************************************************************************************************
====================================================================================================
Classification Report:
               precision    recall  f1-score   support

           0      0.976     0.973     0.975      1320
           1      0.265     0.295     0.280        44

    accuracy                          0.951      1364
   macro avg      0.621     0.634     0.627      1364
weighted avg      0.953     0.951     0.952      1364

====================================================================================================
====================================================================================================
Use DecisionTree to evaluate on the test set
auc: 0.6583333333333332
accuracy score: 0.9552785923753666
====================================================================================================
****************************************************************************************************
precision_micro: 0.9552785923753666     recall_micro: 0.9552785923753666       f1_micro: 0.9552785923753666
precision_macro: 0.6485645971663516     recall_macro: 0.6583333333333333       f1_macro: 0.6532689911529501
****************************************************************************************************
====================================================================================================
Classification Report:
               precision    recall  f1-score   support

           0      0.978     0.976     0.977      1320
           1      0.319     0.341     0.330        44

    accuracy                          0.955      1364
   macro avg      0.649     0.658     0.653      1364
weighted avg      0.957     0.955     0.956      1364

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

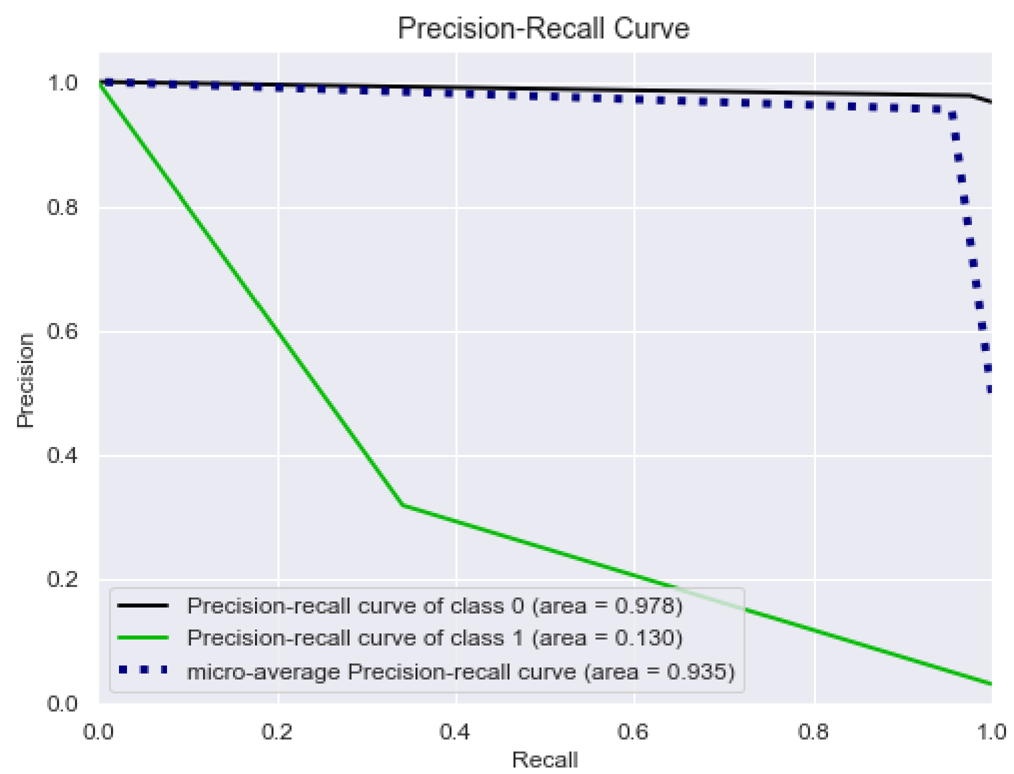





Precision-Recall Curve
Precision
Recall
Precision-recall curve of class 0 (area = 0.976)
Precision-recall curve of class 1 (area = 0.101)
micro-average Precision-recall curve (area = 0.929)


1288
32
29
15
True label
Predicted label


ROC Curves
True Positive Rate
False Positive Rate
ROC curve of class 0 (area = 0.66)
ROC curve of class 1 (area = 0.66)
micro-average ROC curve (area = 0.96)
macro-average ROC curve (area = 0.66)

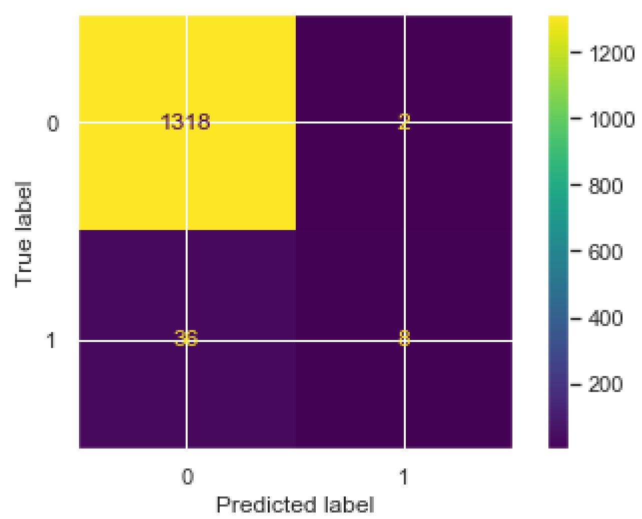

Precision-Recall Curve
Precision
Recall
Precision-recall curve of class 0 (area = 0.978)
Precision-recall curve of class 1 (area = 0.130)
micro-average Precision-recall curve (area = 0.935)

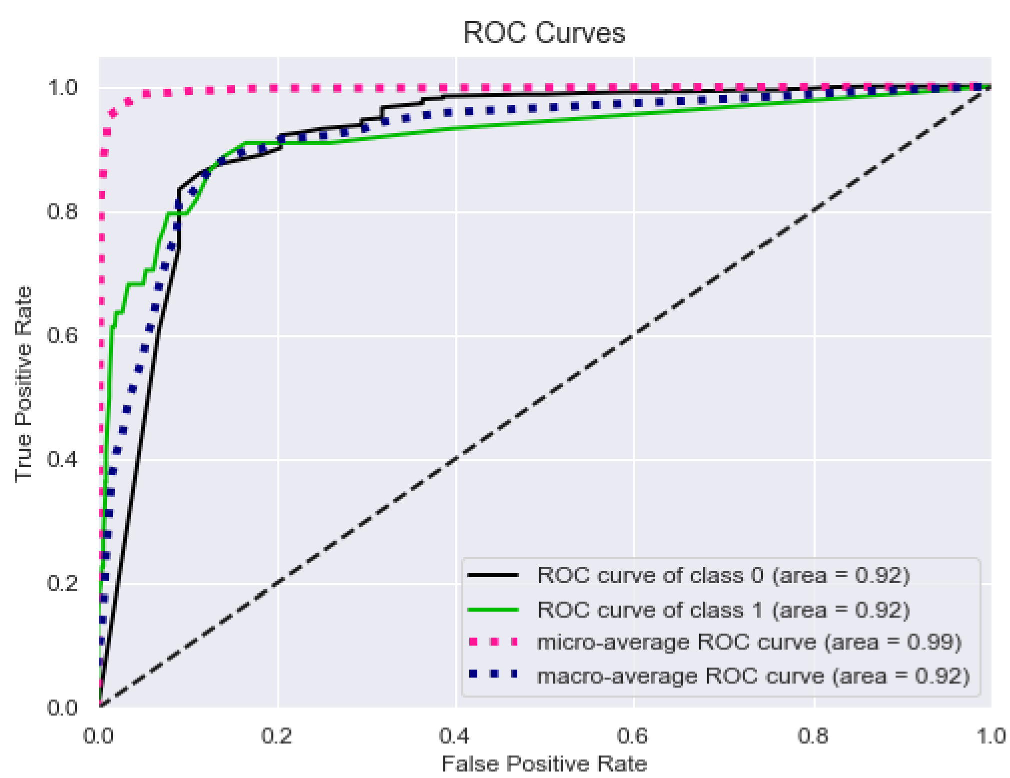
RandomForest

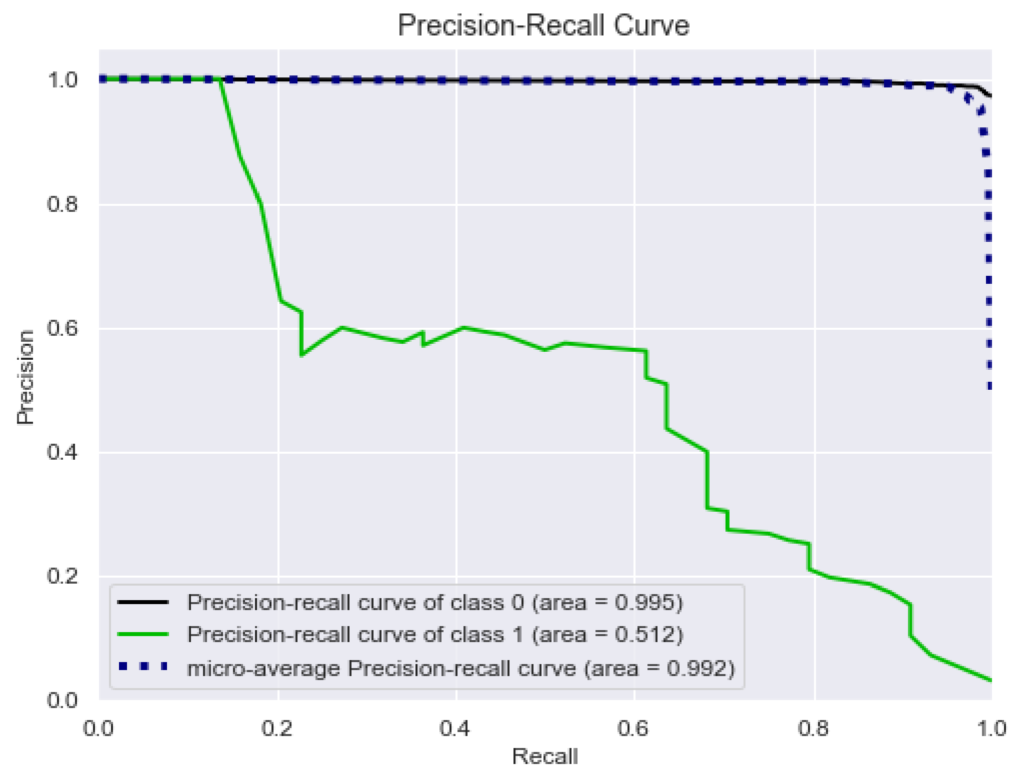
In [285]:

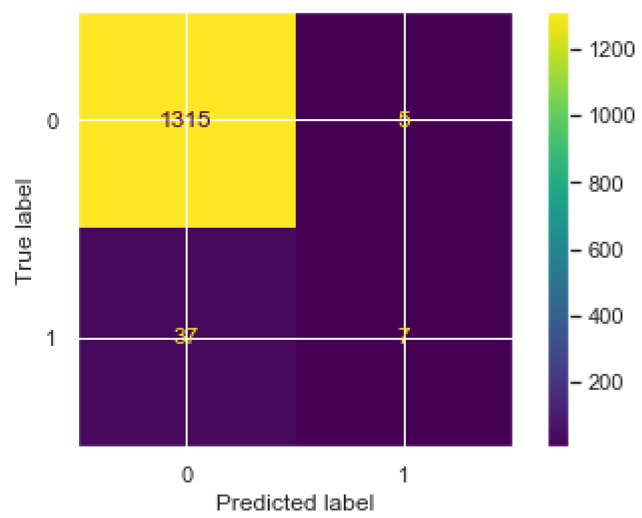
```
RFC = RandomForestClassifier()
print('='*100)
print("Use RandomForest to evaluate on the validation set")
model_eval(RFC,x_train,y_train,x_valid,y_valid)
print('='*100)
print("Use RandomForest to evaluate on the test set")
model_eval(RFC,x_train,y_train,x_test,y_test)
```

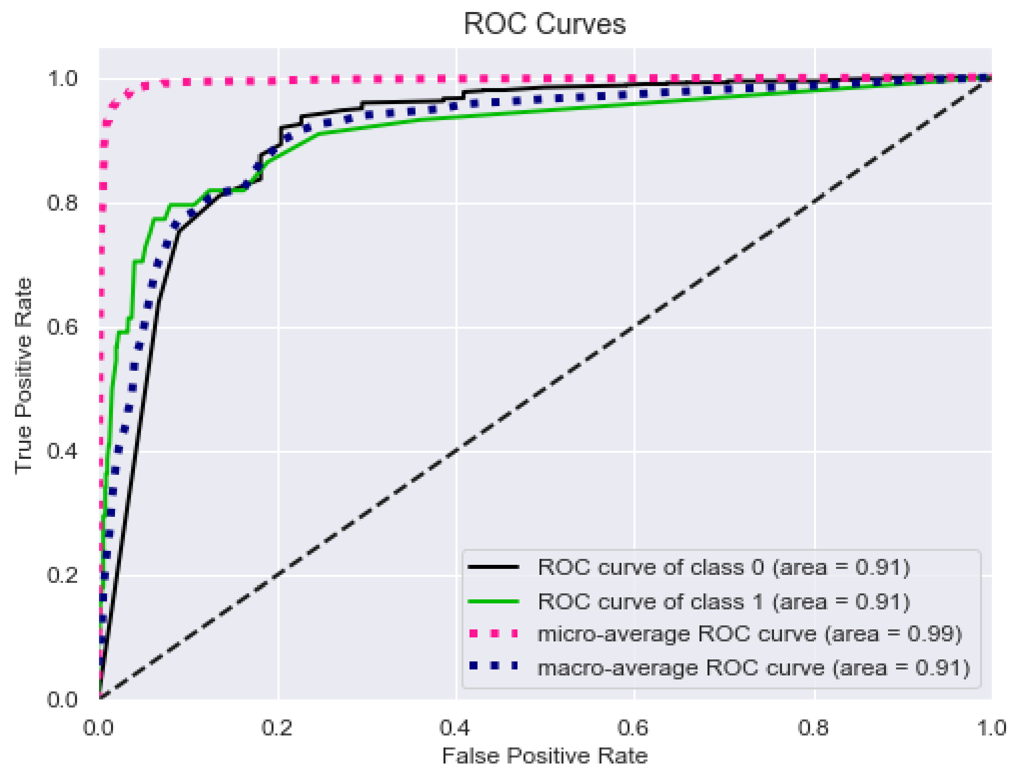
```
====================================================================================================
Use RandomForest to evaluate on the validation set
auc: 0.9173725895316803
accuracy score: 0.9721407624633431
====================================================================================================
****************************************************************************************************
precision_micro: 0.9721407624633431     recall_micro: 0.9721407624633431       f1_micro: 0.9721407624633431
precision_macro: 0.8867060561299853     recall_macro: 0.5901515151515152       f1_macro: 0.641042688163107
****************************************************************************************************
====================================================================================================
Classification Report:
               precision    recall  f1-score   support

           0      0.973     0.998     0.986      1320
           1      0.800     0.182     0.296        44

    accuracy                          0.972      1364
   macro avg      0.887     0.590     0.641      1364
weighted avg      0.968     0.972     0.964      1364

====================================================================================================
====================================================================================================
Use RandomForest to evaluate on the test set
auc: 0.9111053719008264
accuracy score: 0.969208211143695
====================================================================================================
****************************************************************************************************
precision_micro: 0.969208211143695      recall_micro: 0.969208211143695 f1_micro: 0.969208211143695
precision_macro: 0.777983234714004      recall_macro: 0.5776515151515151       f1_macro: 0.6171407185628743
****************************************************************************************************
====================================================================================================
Classification Report:
               precision    recall  f1-score   support

           0      0.973     0.996     0.984      1320
           1      0.583     0.159     0.250        44

    accuracy                          0.969      1364
   macro avg      0.778     0.578     0.617      1364
weighted avg      0.960     0.969     0.961      1364

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

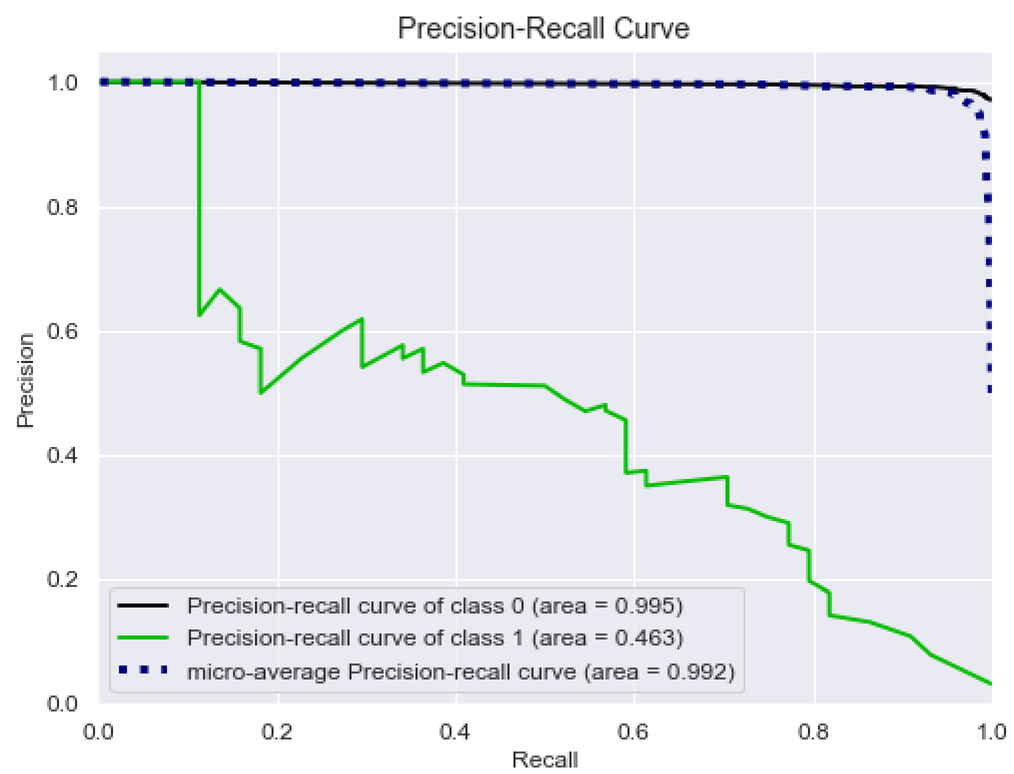





Precision-Recall Curve
Precision
Recall
Precision-recall curve of class 0 (area = 0.995)
Precision-recall curve of class 1 (area = 0.512)
micro-average Precision-recall curve (area = 0.992)


1315
5
37
7
True label
Predicted label


ROC Curves
True Positive Rate
False Positive Rate
ROC curve of class 0 (area = 0.91)
ROC curve of class 1 (area = 0.91)
micro-average ROC curve (area = 0.99)
macro-average ROC curve (area = 0.91)

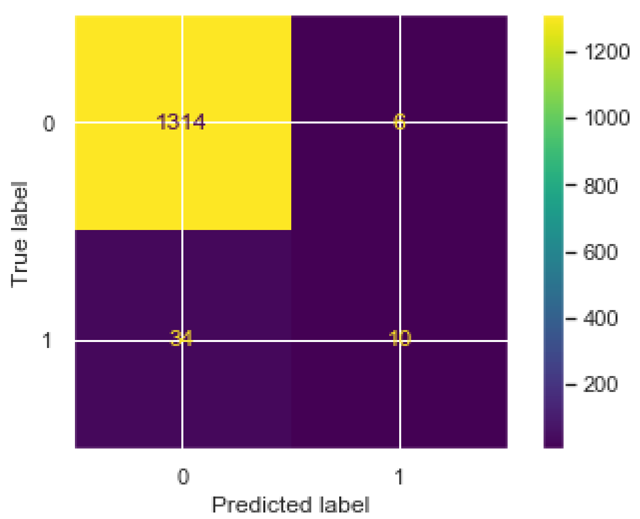

Precision-Recall Curve
Precision
Recall
Precision-recall curve of class 0 (area = 0.995)
Precision-recall curve of class 1 (area = 0.463)
micro-average Precision-recall curve (area = 0.992)

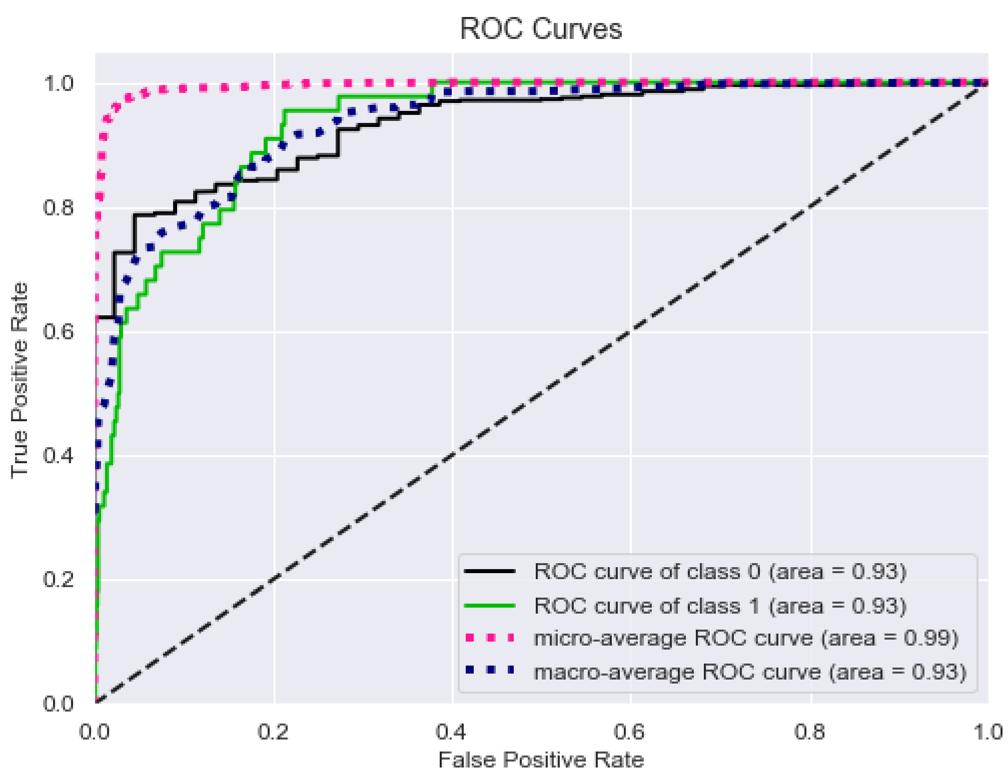
GradientBoosting

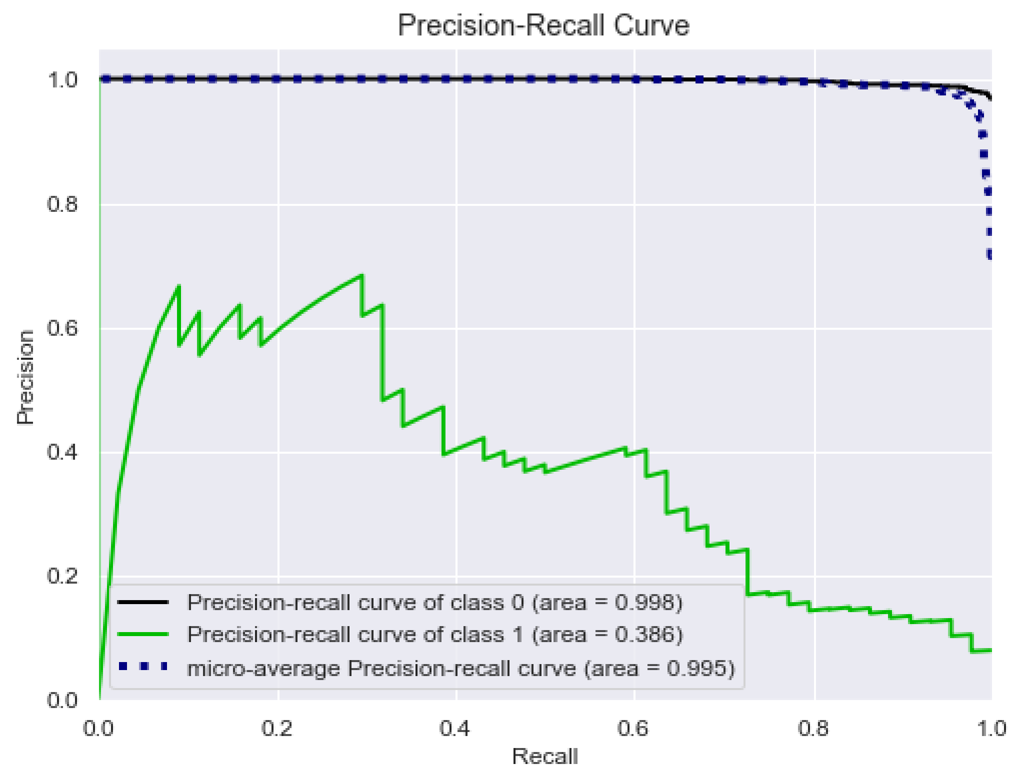
In [286]:

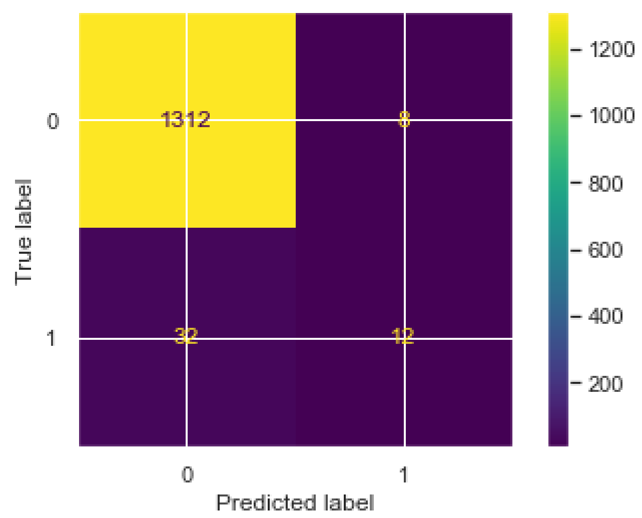
```
GBC = GradientBoostingClassifier()
print('='*100)
print("Use GradientBoostingClassifier to evaluate on the validation set")
model_eval(GBC,x_train,y_train,x_valid,y_valid)
print('='*100)
print("Use GradientBoostingClassifier to evaluate on the test set")
model_eval(GBC,x_train,y_train,x_test,y_test)
```

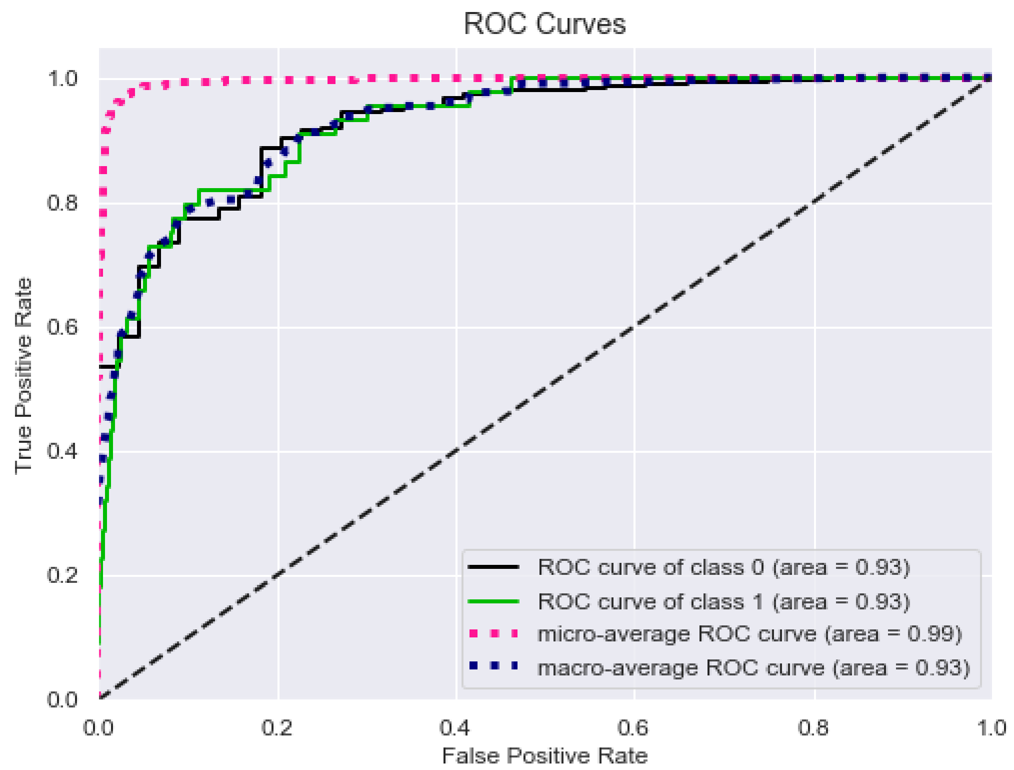
```
==================================================================================================
Use GradientBoostingClassifier to evaluate on the validation set
auc: 0.9332214187327824
accuracy score: 0.9706744868035191
==================================================================================================
**************************************************************************************************
precision_micro: 0.9706744868035191      recall_micro: 0.9706744868035191        f1_micro: 0.9706744868035191
precision_macro: 0.7998887240356083      recall_macro: 0.6113636363636363        f1_macro: 0.6591704147926036
**************************************************************************************************
==================================================================================================
Classification Report:
               precision    recall  f1-score   support

           0      0.975     0.995     0.985      1320
           1      0.625     0.227     0.333        44

    accuracy                          0.971      1364
   macro avg      0.800     0.611     0.659      1364
weighted avg      0.963     0.971     0.964      1364

==================================================================================================
==================================================================================================
Use GradientBoostingClassifier to evaluate on the test set
auc: 0.9269111570247934
accuracy score: 0.9706744868035191
==================================================================================================
**************************************************************************************************
precision_micro: 0.9706744868035191      recall_micro: 0.9706744868035191        f1_micro: 0.9706744868035191
precision_macro: 0.7880952380952381      recall_macro: 0.6333333333333333        f1_macro: 0.6799924924924925
**************************************************************************************************
==================================================================================================
Classification Report:
               precision    recall  f1-score   support

           0      0.976     0.994     0.985      1320
           1      0.600     0.273     0.375        44

    accuracy                          0.971      1364
   macro avg      0.788     0.633     0.680      1364
weighted avg      0.964     0.971     0.965      1364

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

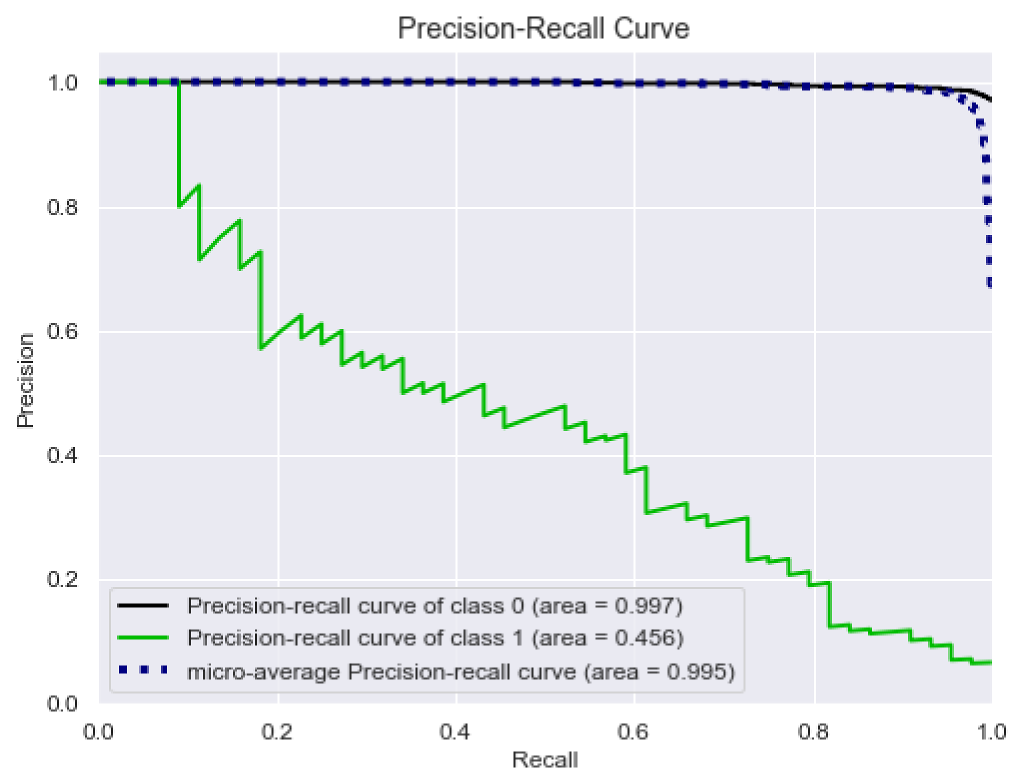





Precision-Recall Curve
Precision
Recall
Precision-recall curve of class 0 (area = 0.998)
Precision-recall curve of class 1 (area = 0.386)
micro-average Precision-recall curve (area = 0.995)


1312
8
32
12
True label
Predicted label
0
1
1200
1000
800
600
400
200

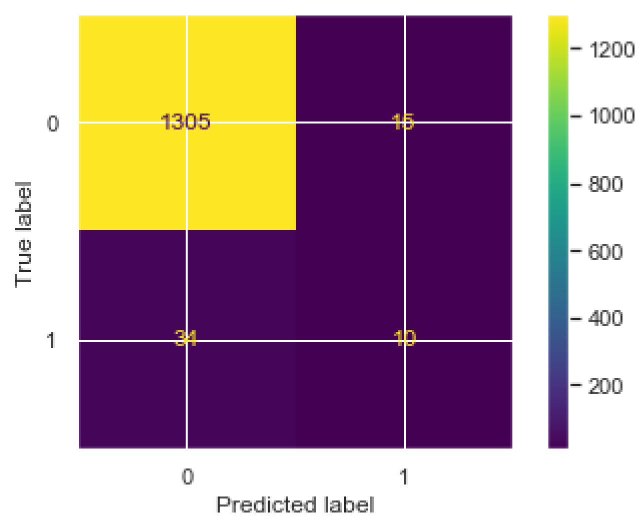

ROC Curves
True Positive Rate
False Positive Rate
ROC curve of class 0 (area = 0.93)
ROC curve of class 1 (area = 0.93)
micro-average ROC curve (area = 0.99)
macro-average ROC curve (area = 0.93)

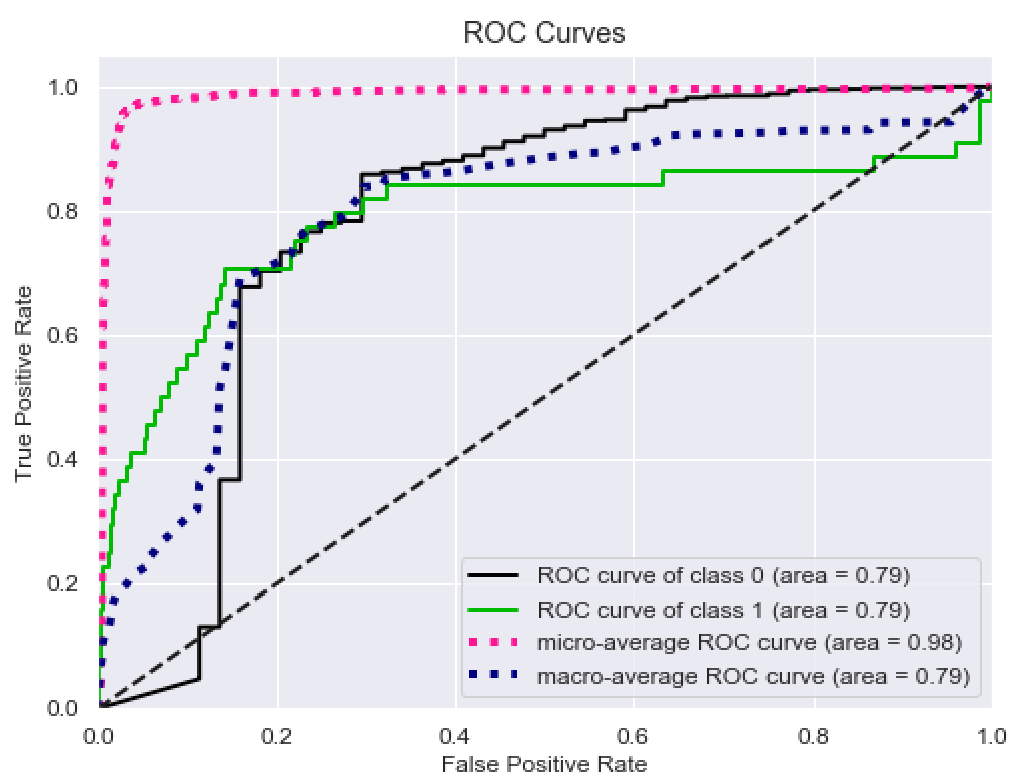

Precision-Recall Curve
Precision
Recall
Precision-recall curve of class 0 (area = 0.997)
Precision-recall curve of class 1 (area = 0.456)
micro-average Precision-recall curve (area = 0.995)

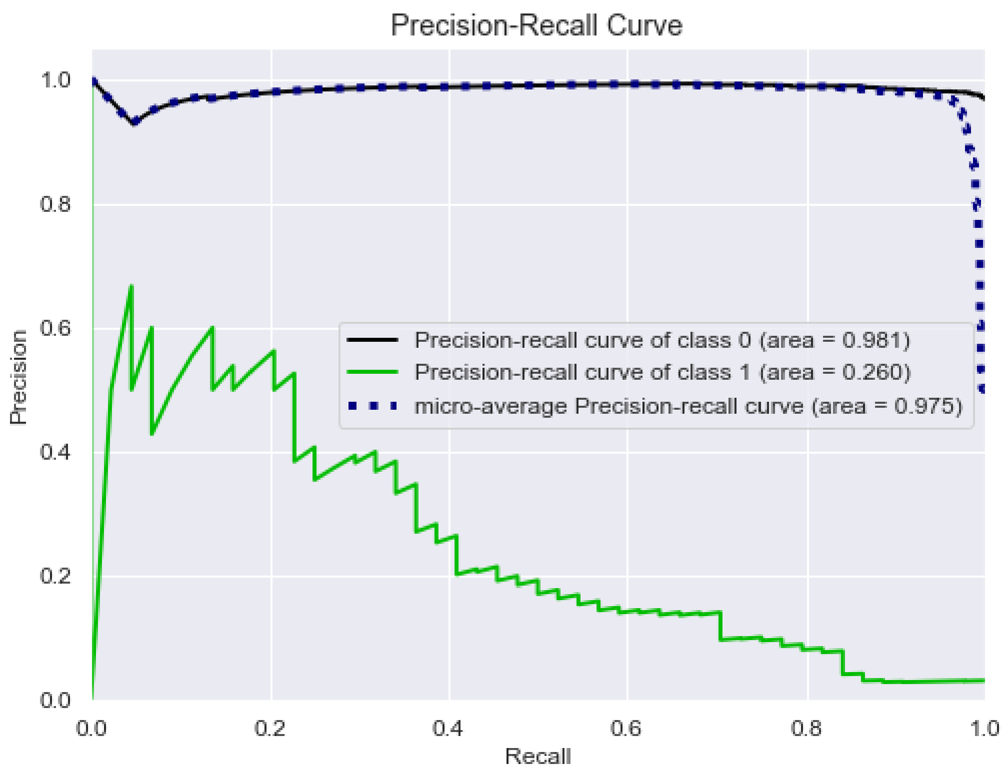
In [287]:

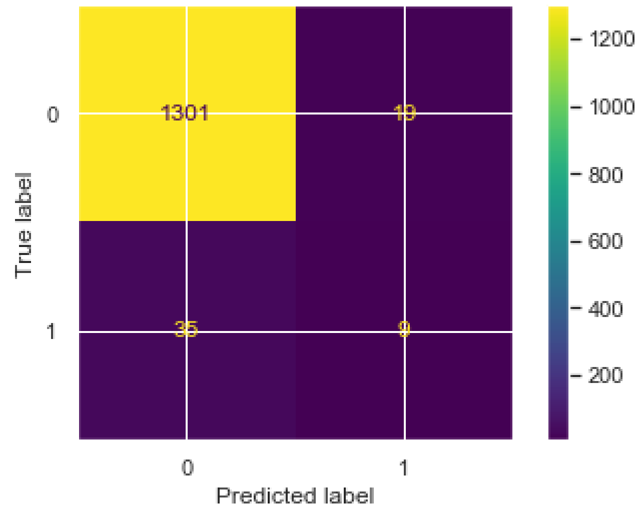
```
MLP = MLPClassifier()
print('='*100)
print("Use MLP to evaluate on the validation set")
model_eval(MLP,x_train,y_train,x_valid,y_valid)
print('='*100)
print("Use MLP to evaluate on the test set")
model_eval(MLP,x_train,y_train,x_test,y_test)
```

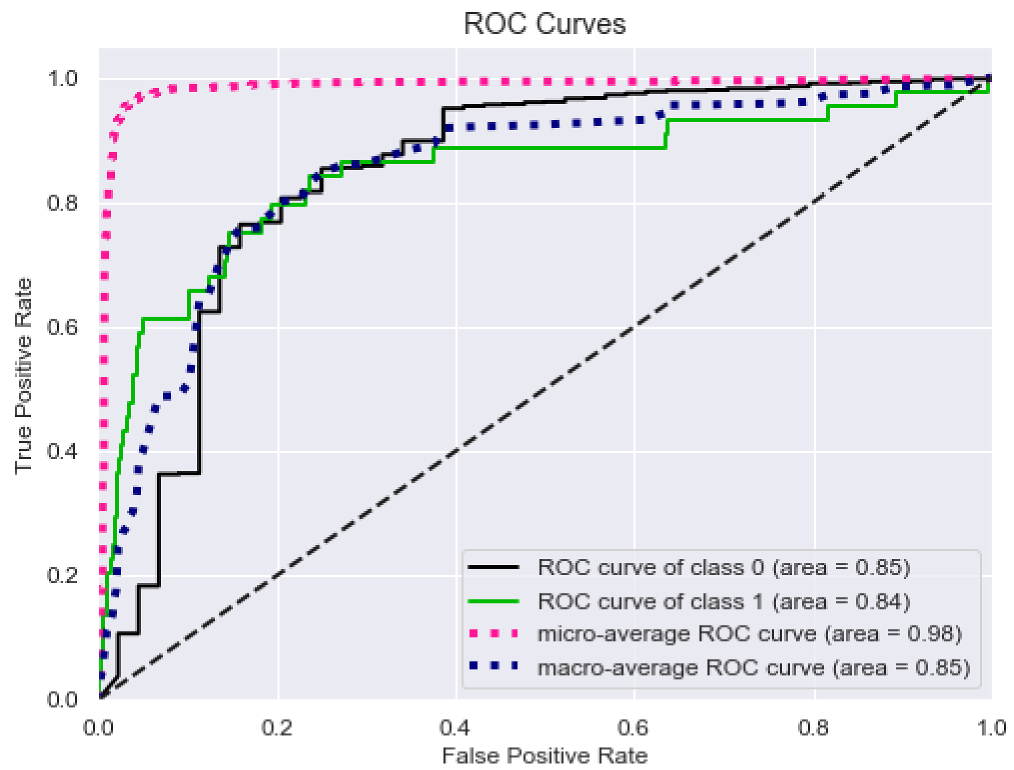
```
========================================================================================================
Use MLP to evaluate on the validation set
auc: 0.7850034435261708
accuracy score: 0.9640762463343109
========================================================================================================
********************************************************************************************************
precision_micro: 0.9640762463343109     recall_micro: 0.9640762463343109        f1_micro: 0.9640762463343109
precision_macro: 0.6873039581777446     recall_macro: 0.6079545454545454        f1_macro: 0.6357135460099962
********************************************************************************************************
========================================================================================================
Classification Report:
               precision    recall  f1-score   support

           0      0.975     0.989     0.982      1320
           1      0.400     0.227     0.290        44

    accuracy                          0.964      1364
   macro avg      0.687     0.608     0.636      1364
weighted avg      0.956     0.964     0.959      1364

========================================================================================================
========================================================================================================
Use MLP to evaluate on the test set
auc: 0.8448347107438016
accuracy score: 0.9604105571847508
========================================================================================================
********************************************************************************************************
precision_micro: 0.9604105571847508     recall_micro: 0.9604105571847508        f1_micro: 0.9604105571847508
precision_macro: 0.6476154833190761     recall_macro: 0.5950757575757576        f1_macro: 0.6148343373493975
********************************************************************************************************
========================================================================================================
Classification Report:
               precision    recall  f1-score   support

           0      0.974     0.986     0.980      1320
           1      0.321     0.205     0.250        44

    accuracy                          0.960      1364
   macro avg      0.648     0.595     0.615      1364
weighted avg      0.953     0.960     0.956      1364

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

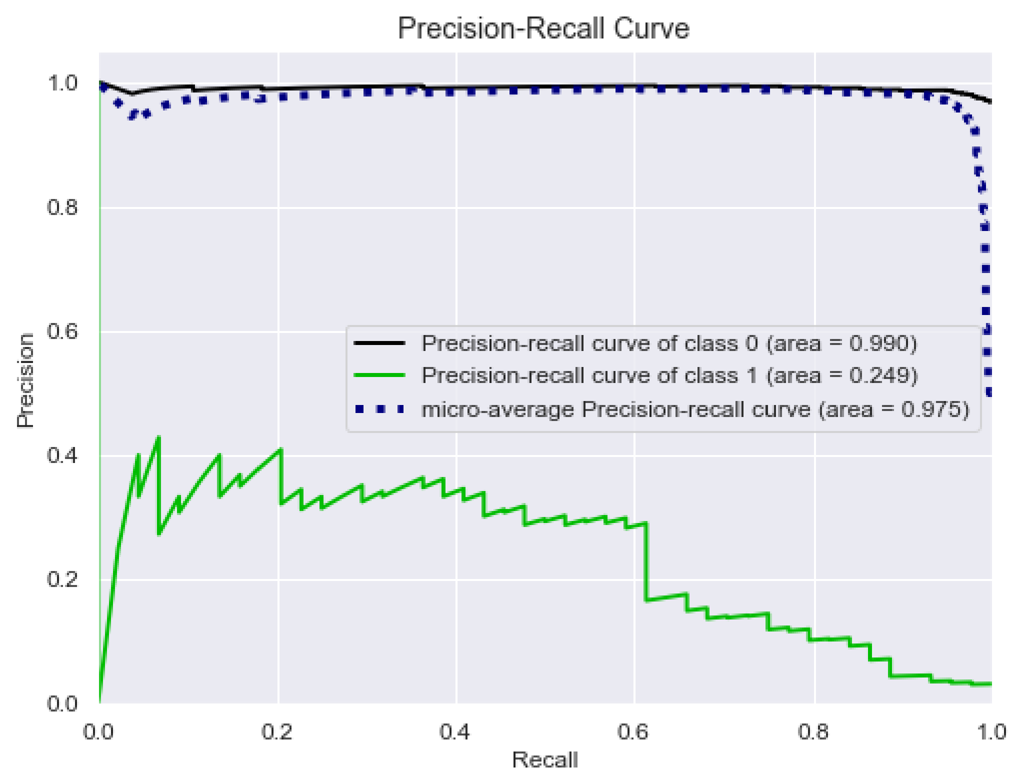





Precision-Recall Curve
Precision
Recall
Precision-recall curve of class 0 (area = 0.981)
Precision-recall curve of class 1 (area = 0.260)
micro-average Precision-recall curve (area = 0.975)


1301
19
35
9
True label
Predicted label
1200
1000
800
600
400
200


ROC Curves
True Positive Rate
False Positive Rate
ROC curve of class 0 (area = 0.85)
ROC curve of class 1 (area = 0.84)
micro-average ROC curve (area = 0.98)
macro-average ROC curve (area = 0.85)

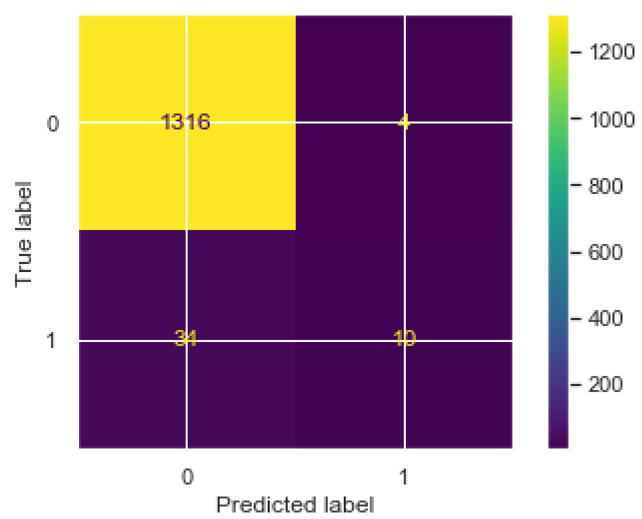

Precision-Recall Curve
Precision
Recall
Precision-recall curve of class 0 (area = 0.990)
Precision-recall curve of class 1 (area = 0.249)
micro-average Precision-recall curve (area = 0.975)

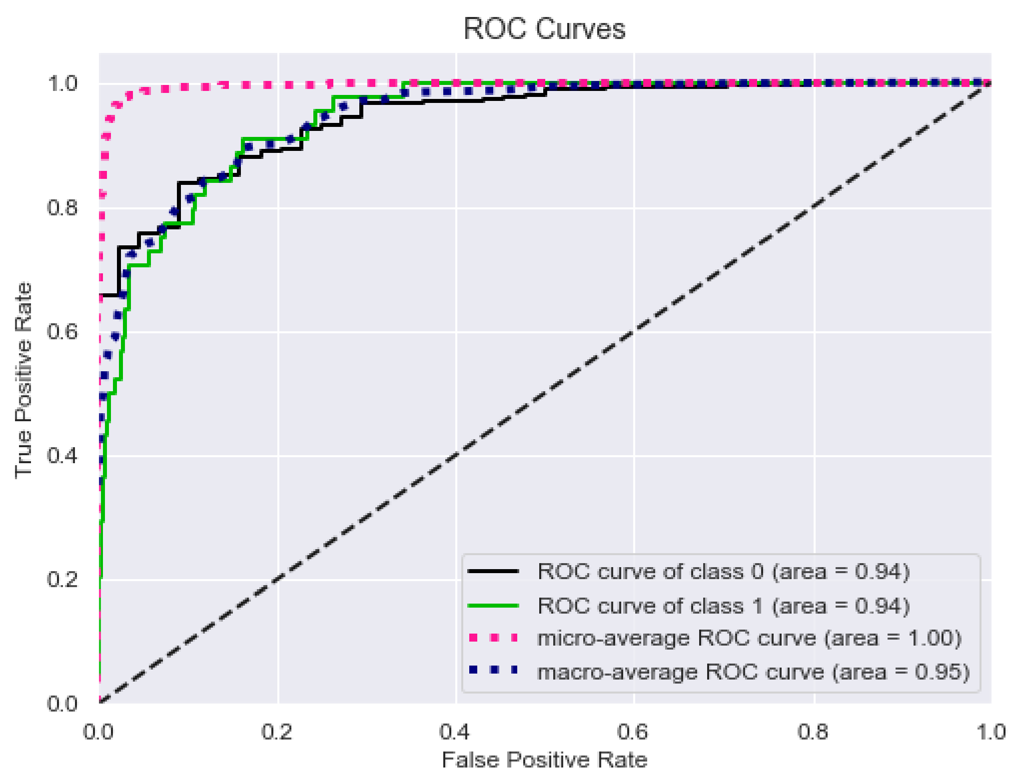
CatBoostClassifier

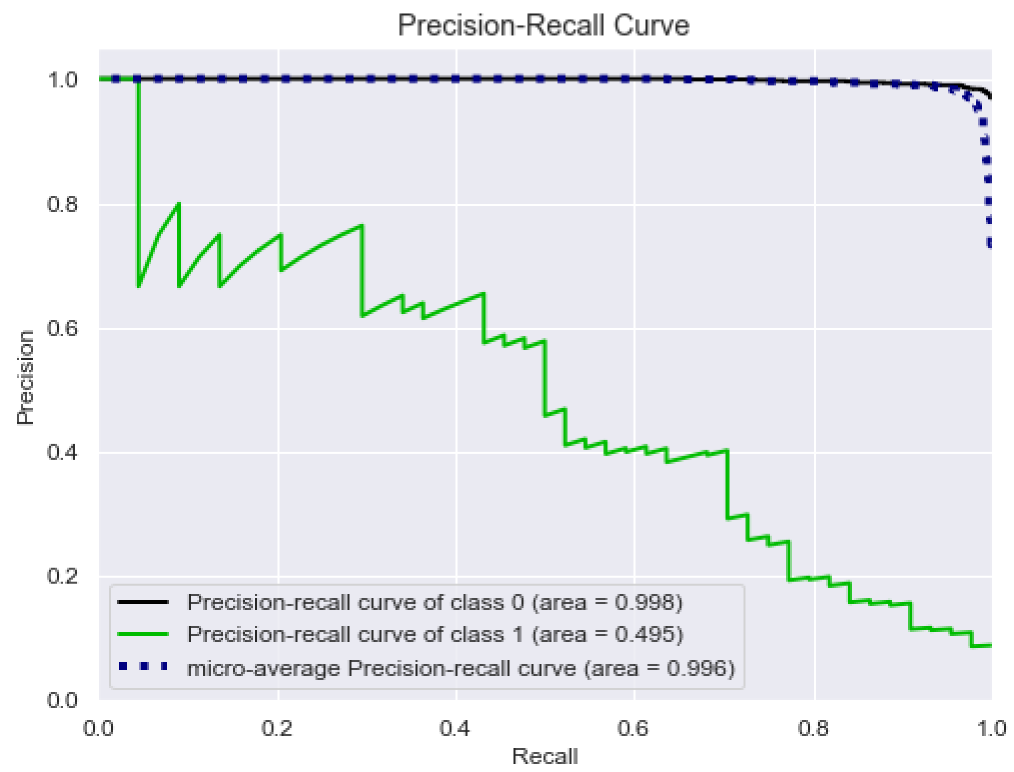
In [290]:

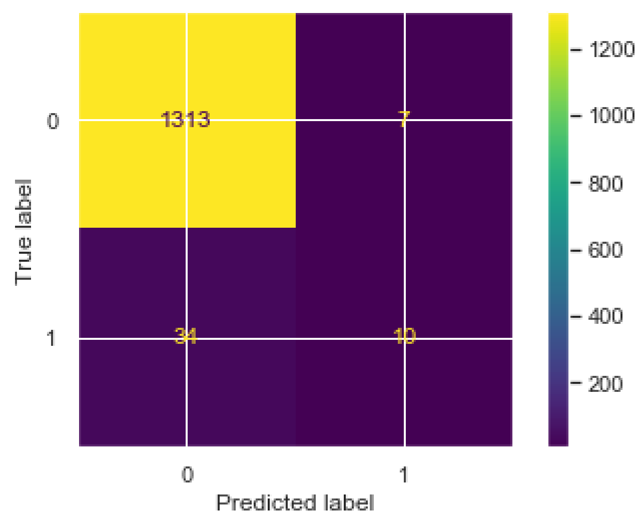
```
CAT = CatBoostClassifier(n_estimators=300,verbose = 0)
print('='*100)
print("Use CAT to evaluate on the validation set")
model_eval(CAT,x_train,y_train,x_valid,y_valid)
print('='*100)
print("Use CAT to evaluate on the test set")
model_eval(CAT,x_train,y_train,x_test,y_test)
```

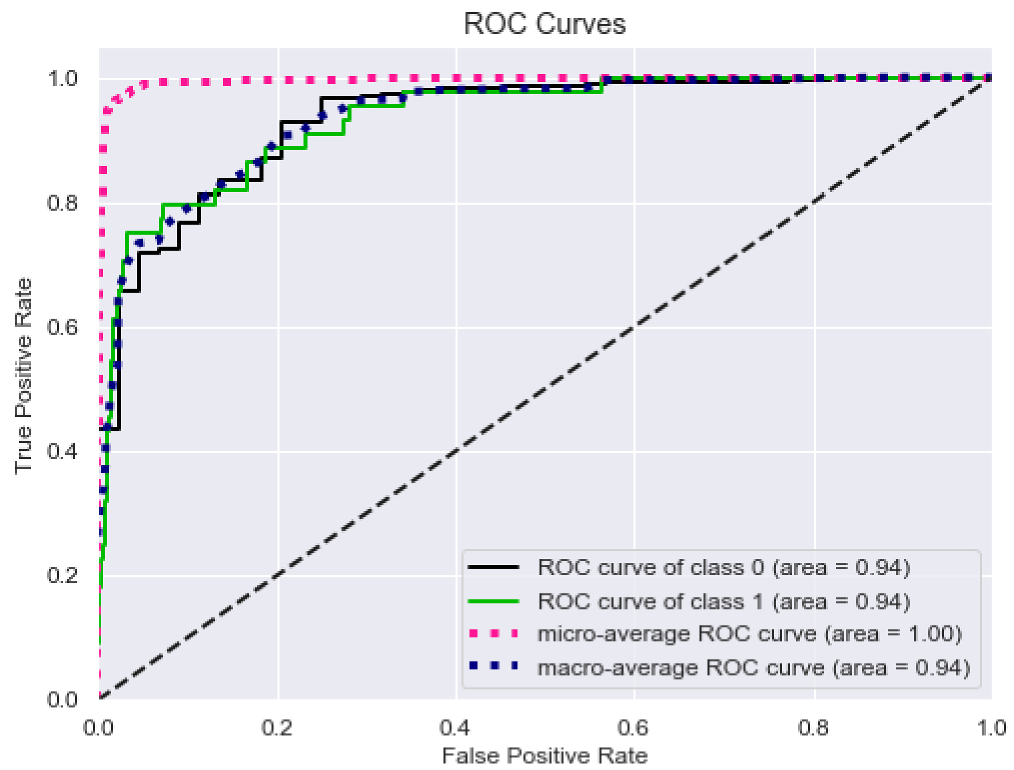
```
====================================================================================================
Use CAT to evaluate on the validation set
auc: 0.9442665289256199
accuracy score: 0.9721407624633431
====================================================================================================
****************************************************************************************************
precision_micro: 0.9721407624633431     recall_micro: 0.9721407624633431       f1_micro: 0.9721407624633431
precision_macro: 0.8445502645502645     recall_macro: 0.6121212121212121       f1_macro: 0.6652976882345344
****************************************************************************************************
====================================================================================================
Classification Report:
              precision    recall  f1-score   support

           0      0.975     0.997     0.986      1320
           1      0.714     0.227     0.345        44

    accuracy                          0.972      1364
   macro avg      0.845     0.612     0.665      1364
weighted avg      0.966     0.972     0.965      1364

====================================================================================================
====================================================================================================
Use CAT to evaluate on the test set
auc: 0.9350034435261708
accuracy score: 0.9699413489736071
====================================================================================================
****************************************************************************************************
precision_micro: 0.9699413489736071     recall_micro: 0.9699413489736071       f1_micro: 0.9699413489736071
precision_macro: 0.7814970086029958     recall_macro: 0.6109848484848485       f1_macro: 0.6562478870469061
****************************************************************************************************
====================================================================================================
Classification Report:
              precision    recall  f1-score   support

           0      0.975     0.995     0.985      1320
           1      0.588     0.227     0.328        44

    accuracy                          0.970      1364
   macro avg      0.781     0.611     0.656      1364
weighted avg      0.962     0.970     0.963      1364

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

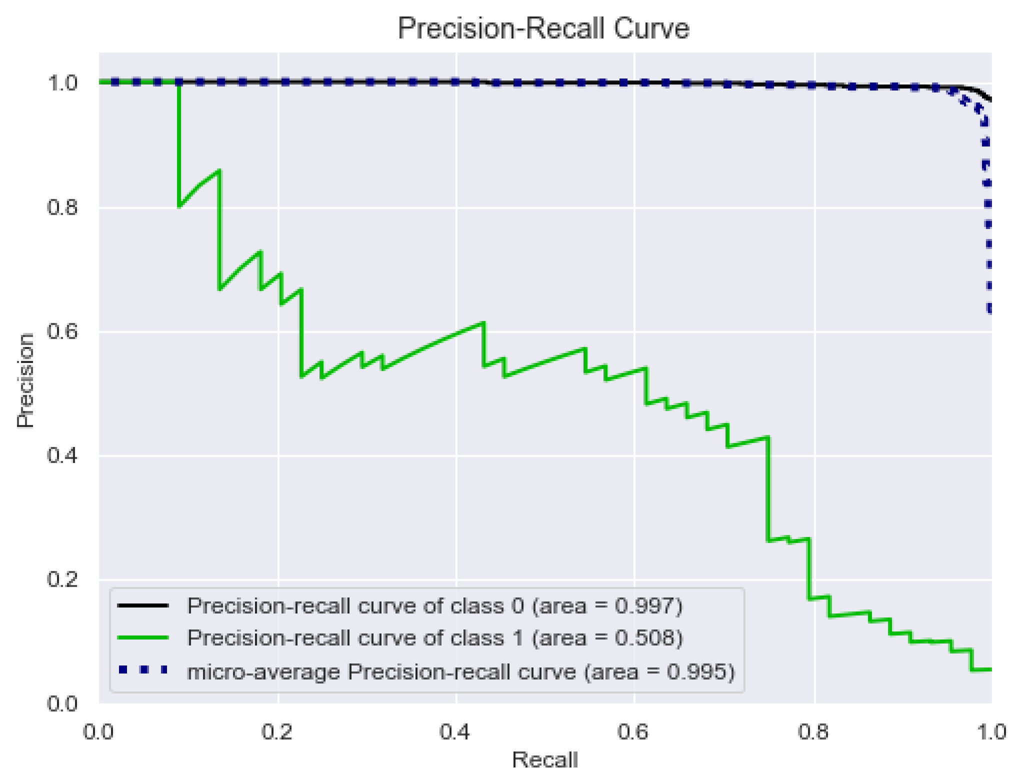





Precision-Recall Curve
Precision
Recall
1.0
0.8
0.6
0.4
0.2
0.0
0.0
0.2
0.4
0.6
0.8
1.0
Precision-recall curve of class 0 (area = 0.998)
Precision-recall curve of class 1 (area = 0.495)
micro-average Precision-recall curve (area = 0.996)


True label
Predicted label
0
1
0
1
1313
7
34
10
1200
1000
800
600
400
200


ROC Curves
True Positive Rate
False Positive Rate
1.0
0.8
0.6
0.4
0.2
0.0
0.0
0.2
0.4
0.6
0.8
1.0
ROC curve of class 0 (area = 0.94)
ROC curve of class 1 (area = 0.94)
micro-average ROC curve (area = 1.00)
macro-average ROC curve (area = 0.94)


Precision-Recall Curve
Precision
Recall
1.0
0.8
0.6
0.4
0.2
0.0
0.0
0.2
0.4
0.6
0.8
1.0
Precision-recall curve of class 0 (area = 0.997)
Precision-recall curve of class 1 (area = 0.508)
micro-average Precision-recall curve (area = 0.995)

In [ ]:

```

```