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# Bankruptcy Prediction for Polish Companies

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## Overview

In this study, I will analyze the financial standings of the Polish companies to identify whether the company will banckrupt in 1-5 years. I will use the Ensemble Method 'XGBoost', eXtreme Gradient Boosting, for classification.



## Repository Content

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- data: directory containing the data files
- deliverables: directory containing the files to be submitted for project review
- figures: directory containing figures/images
- notUsed: directory containing some preliminary analysis, which is not part of the latest version of the project
- saved\_model\_history: directory containing the saved models
- .gitignore: text file that contains the list of files/directories that should not be tracked by git repository
- README.md: markdown file that describes the git repository and the project
- analysis\_1\_explore.ipynb: jupyter notebook for analysis part 1, data exploring
- analysis\_2\_imbalance.ipynb: jupyter notebook for analysis part 2, class imbalance study for Data 3
- analysis\_3\_data3.ipynb: jupyter notebook for analysis part 3, XGBoost Classification for Data 3
- analysis\_4\_dataAll.ipynb: jupyter notebook for analysis part 4, XGBoost Classification for all data sets AND Interpretation of Results
- functions.py: python file containing the functions used in the analysis

## Project Outline

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- Business Problem
- Data
- Methods
- Analysis and Results

- Class Imbalance
- Model Optimization for Data 3
- Model Performance on All Datasets
- Final Model
- Interpretation of Results
- Conclusion
- Future Work

## Business Problem

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KPMG, international corporate financial consulting firm, hired me to analyze the financial standing of the Polish companies. The goal of the analysis is identifying whether the business will go to bankruptcy in 1-5 years or not. KMPG will use the results of this study to provide an early warning to Polish business clients on their financial standings, so they can take preventive actions.

## Data

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The data contains the financial information and bankruptcy status of Polish companies. It is collected from Emerging Markets Information Service (EMIS, [Web Link]).

The data was collected in the period of

- 2000-2012 for the bankrupt companies
- 2007-2013 for the still operating companies

Depending on the forecasting period, the data is classified in five categories/datasets.:

- 1st Year: the data contains financial rates from 1st year of the forecasting period and corresponding class label that indicates bankruptcy status after 5 years (1year.arff).
- 2nd Year: the data contains financial rates from 2nd year of the forecasting period and corresponding class label that indicates bankruptcy status after 4 years (2year.arff).
- 3rd Year: the data contains financial rates from 3rd year of the forecasting period and corresponding class label that indicates bankruptcy status after 3 years (3year.arff).
- 4th Year: the data contains financial rates from 4th year of the forecasting period and corresponding class label that indicates bankruptcy status after 2 years (4year.arff).

- 5th Year: the data contains financial rates from 5th year of the forecasting period and corresponding class label that indicates bankruptcy status after 1 year (1year.arff).

There are 64 attributes for each company. The list of the attributes and their descriptions can be found on UIC page:

<https://archive.ics.uci.edu/ml/datasets/Polish+companies+bankruptcy+data>

In my analysis, I name the five dataset files as:

- Data 1: '1year.arff'
- Data 2: '2year.arff'
- Data 3: '3year.arff'
- Data 4: '4year.arff'
- Data 5: '5year.arff'

The number of companies in each dataset and class distributions:

Data #	Total	Still Operating (class=0)	Bankrupt (class=1)
Data 1	7027	6756	271
Data 2	10173	9773	400
Data 3	10503	10008	495
Data 4	9792	9277	515
Data 5	5910	5500	410

## Data Cleaning

- No cleaning applied to data used in this analysis. XGBoost Classifier can handle the missing values and outliers.
- Preliminary study showed that, model performance with cleaned data is significantly lower.

## Method

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I will use Ensemble Method 'XGBoost', eXtreme Gradient Boosting, for classification.

This is a binary classification problem, since my goal is to identify whether the company will bankrupt or not.

Evaluation metric for data training = 'logloss'

I will focus on the performance of 'recall' metric in order to minimize false negatives. Besides, I will also keep an eye on 'precision', 'f1', 'accuracy', and 'AUC' metrics.

## Analysis and Results

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Initially, I explored the XGBoost Classifier models on Data 3. After determining the best model designs, I applied them on other datasets and compare the results.

In each dataset, I have used 80% of data for training and 20% for testing.

### Class Imbalance

Data 3 is used for Class Imbalance Study.

The default XGBClassifier init parameters are used (except max\_depth and scale\_pos\_weight).

The class imbalance is one of the main issues in this data.

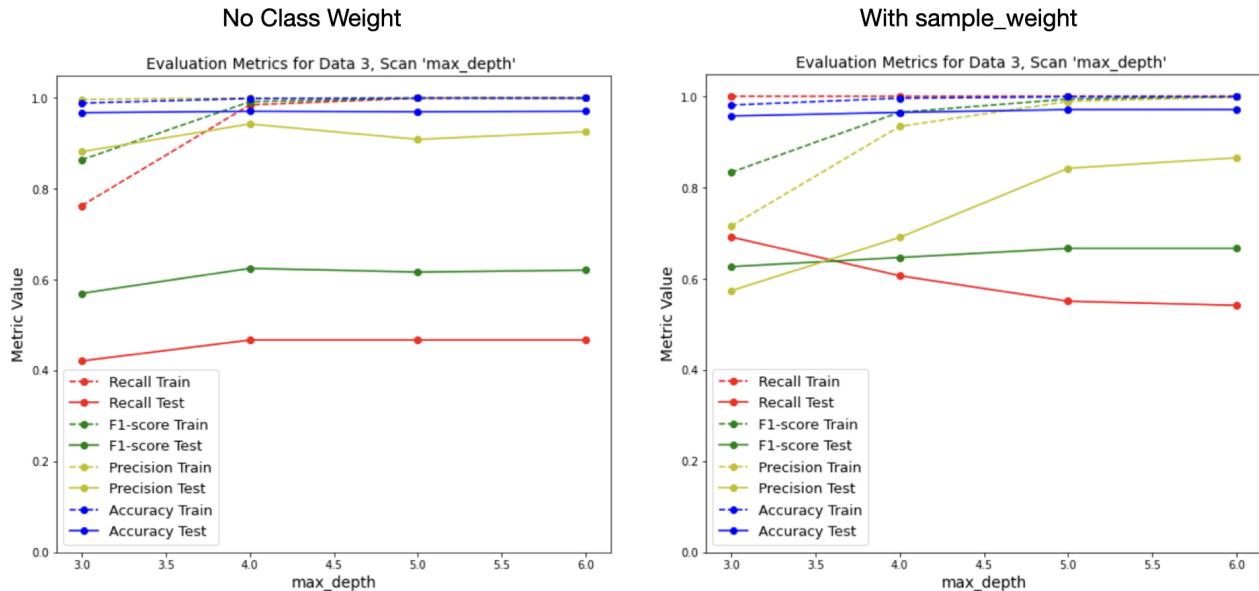
Imbalance Ratio = (# of class 0 companies) / (# of class 1 companies)

Data #	Imbalance Ratio	Sqrt of Imbalance Ratio
Data 1	24.93	4.99
Data 2	24.43	4.94
Data 3	20.22	4.50
Data 4	18.01	4.24
Data 5	13.41	3.66

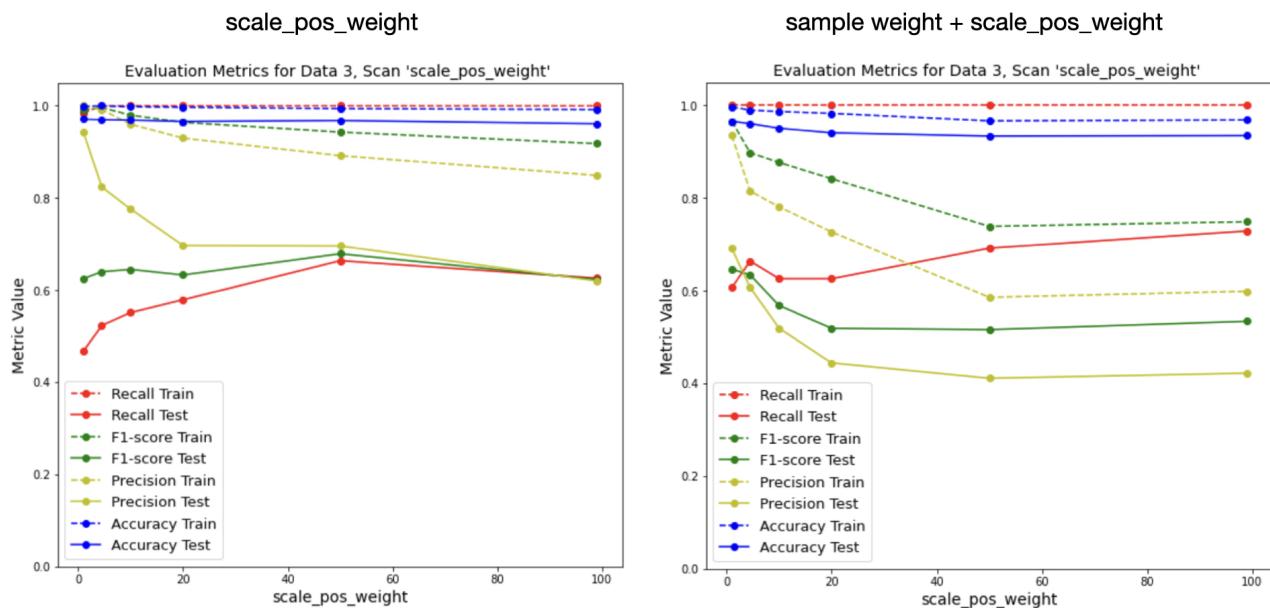
There are two approaches to deal with the class imbalance.

1. **sample\_weight**: class weight parameter when training the data. The class weights are calculated for each dataset separately during training.
2. **scale\_pos\_weight**: class weight parameter when initiating the classifier. I provide certain constant values to initiate the classifier.

The graphs below show the effect of sample\_weight on model performance at several max\_depth values for Data 3. Left: No sample\_weight applied. Right: sample\_weight method applied.



The graphs below shows the performance of model as sample\_pos\_weight varies, at max\_depth=4 for Data 3. Left: only scale\_pos\_weight applied. Right: both sample\_weight + scale\_pos\_weight applied.



The table below shows the comparison of imbalance treatment approaches at max\_depth=4 for Data 3:

		precision	recall	f1	accuracy	auc
Params						
<b>sample_weight</b>	<b>Train</b>	0.935	1.000	0.966	0.997	1.000
	<b>Test</b>	0.691	0.607	0.647	0.966	0.920
<b>scale_pos_weight=50</b>	<b>Train</b>	0.892	1.000	0.943	0.994	1.000
	<b>Test</b>	0.696	0.664	0.679	0.968	0.932
<b>sample_weight + scale_pos_weight=4.5</b>	<b>Train</b>	0.815	1.000	0.898	0.990	1.000
	<b>Test</b>	0.607	0.664	0.634	0.961	0.922
<b>sample_weight + scale_pos_weight=50</b>	<b>Train</b>	0.586	1.000	0.739	0.967	1.000
	<b>Test</b>	0.411	0.692	0.516	0.934	0.911

## Findings:

- Applying sample\_weight or sample\_pos\_weight improves the model performance:
  - increases recall
  - decreases overfitting
- sample\_weight is more effective at lower max\_depth (3 or 4)
- Using both approaches together provides a better result.
- Optimum configurations:
  - max\_depth=4: sample\_weight + scale\_pos\_weight=4.5 (~square root of imbalance ratio)
  - max\_depth=5: sample\_weight + scale\_pos\_weight=20 (~imbalance ratio)
  - max\_depth=6: sample\_weight + scale\_pos\_weight=20 (~imbalance ratio)

## Model Optimization for Data 3

I performed a detailed analysis on Data 3.

The overfitting looked like a main issue for this study. I tried to control overfitting by tuning the XGBoost Classifier Parameters, while trying to improve the model at the same time.

I firstly used GridSearchCV on few parameters to obtain best performance parameters. Then, I looked in parameters that effect overfitting.

The parameters that can affect overfitting are grouped in four categories:

- 1. Boosting Rounds
  - n\_estimators
- 2. Pruning:
  - max\_depth
  - min\_child\_weight
  - gamma
- 3. Regularization:
  - learning\_rate
  - max\_delta\_step
  - reg\_lambda
  - reg\_alpha
- 4. Sampling
  - subsample
  - colsample\_bytree

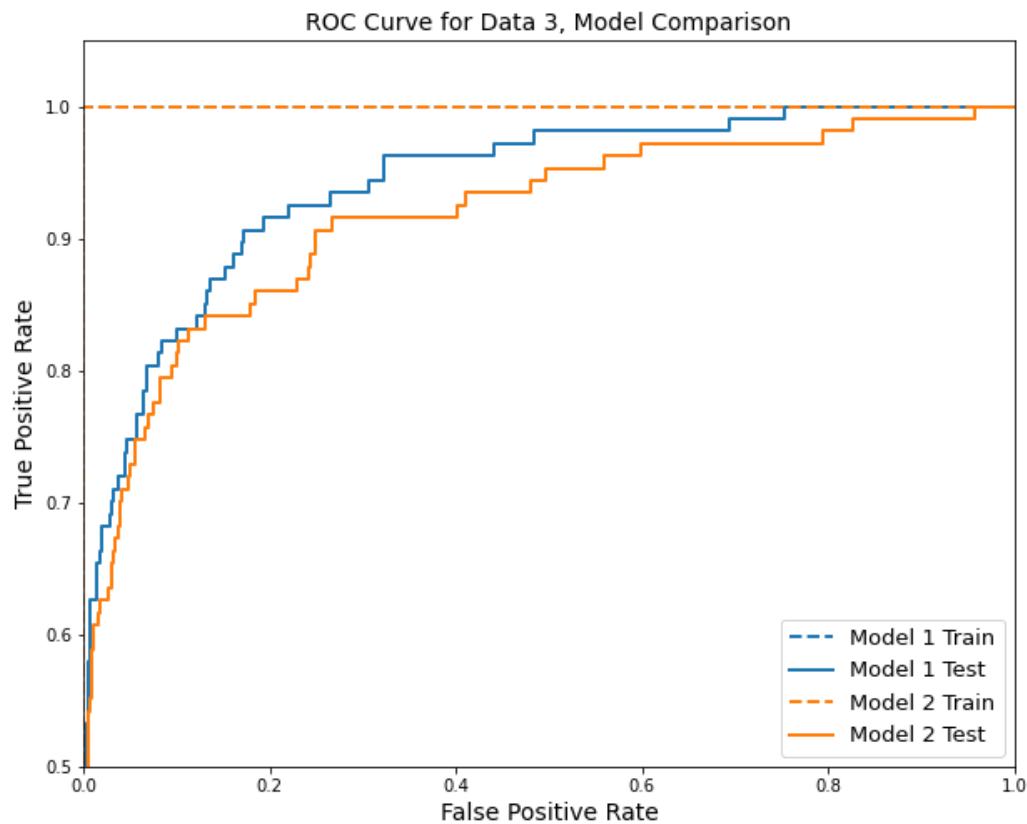
I started with baseline model and did improve the performance step by step.

### **Model 1: Baseline Model**

- Default XGBClassifier parameters:
  - base\_score=0.5, booster='gbtree', colsample\_bylevel=1, colsample\_bynode=1, colsample\_bytree=1, eval\_metric='logloss', gamma=0, gpu\_id=-1, importance\_type='gain', interaction\_constraints='', learning\_rate=0.300000012, max\_delta\_step=0, **max\_depth=6**, min\_child\_weight=1, missing=nan, monotone\_constraints='()', n\_estimators=100, n\_jobs=4, num\_parallel\_tree=1, random\_state=42, reg\_alpha=0, reg\_lambda=1, scale\_pos\_weight=1, subsample=1, tree\_method='exact', validate\_parameters=1, verbosity=None

### **Model 2: Model with Class Imbalance treated**

- Optimized class balancing method used, in addition to the XGBClassifier default parameters.
- max\_depth=6: sample\_weight + scale\_pos\_weight=20 (~imbalance ratio)
- Model performance increased compared to Model 1.
- See the ROC curve graph below and summary metrics table at the end of 'Model Optimization for Data 3' section.



### Model 3: Model after GridSearchCV Parameter Tuning

- I have applied GridSearchCV on the parameters: n\_estimators, max\_depth, min\_child\_weight, learning\_rate, subsample
- Scoring = 'f1'. Even though, my focus is on 'recall', I use 'f1' in GridSearchCV to obtain overall good performance.
- I only used sample\_weight method for parameter tuning. I chose not to use 'scale\_pos\_weight' during grid search, since the optimum value varies depending on the max\_depth. After parameter tuning, I applied the optimum scale\_pos\_weight on data training.
- The best parameters:
  - n\_estimators = 150
  - max\_depth = 5
  - min\_child\_weight = 1
  - learning\_rate = 0.20
  - subsample = 1

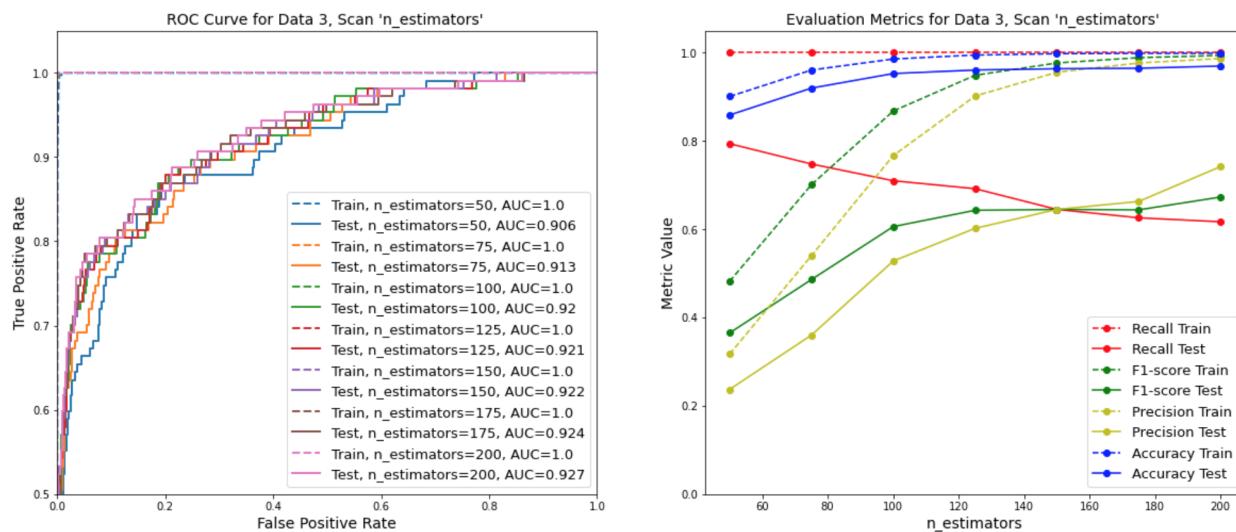
- The GridSearch Model improved the model performance.
- However, the large overfitting still exists.
- See summary metrics table at the end of 'Model Optimization for Data 3' section.

### Model 7: Optimized Model at max\_depth=5

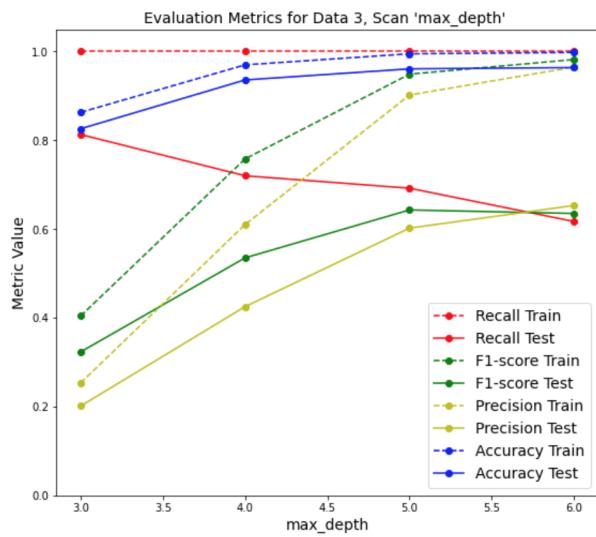
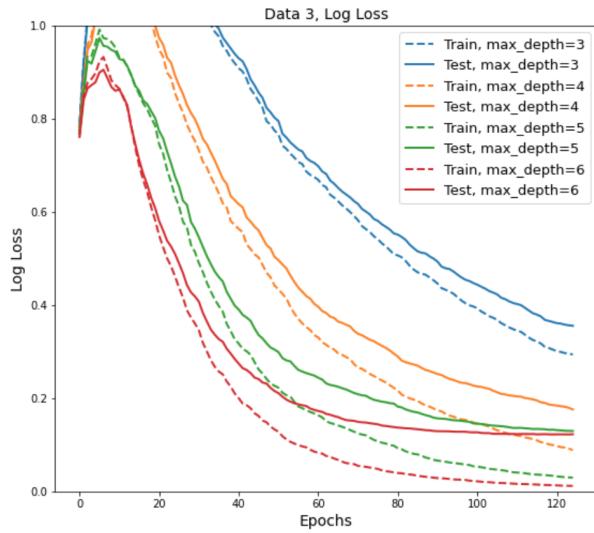
- From Model 4 to Model 7, I have tried to tune the parameters, at max\_depth=5, in order to
  - decrease overfitting
  - increase 'recall' metric
  - avoid large decrease in 'precision' as much as possible
- I have scanned the parameters, which affects the overfitting, step by step in an order as listed at the beginning of 'Model Optimization for Data 3' section.
- Model 7 has the optimum design at max\_depth=5 for Data 3.

The scan results of the selected parameters are shown below:

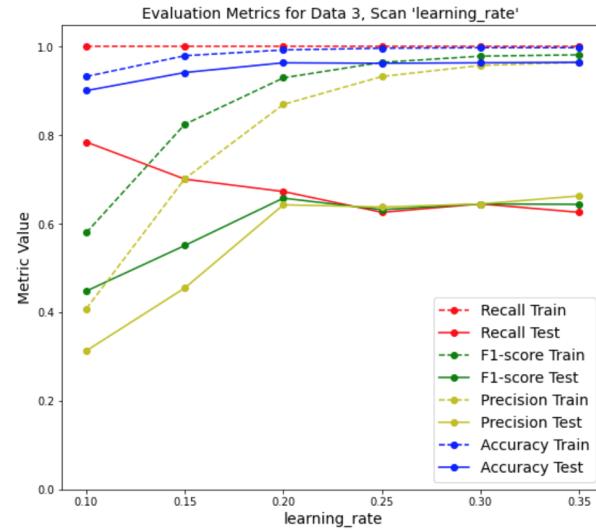
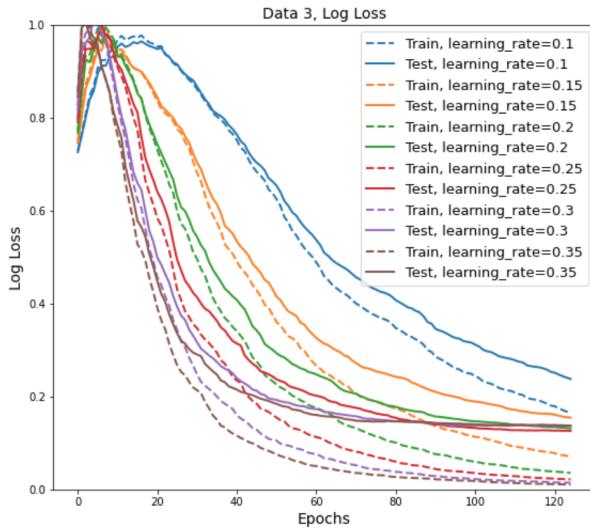
- n\_estimators: ROC curve and metrics



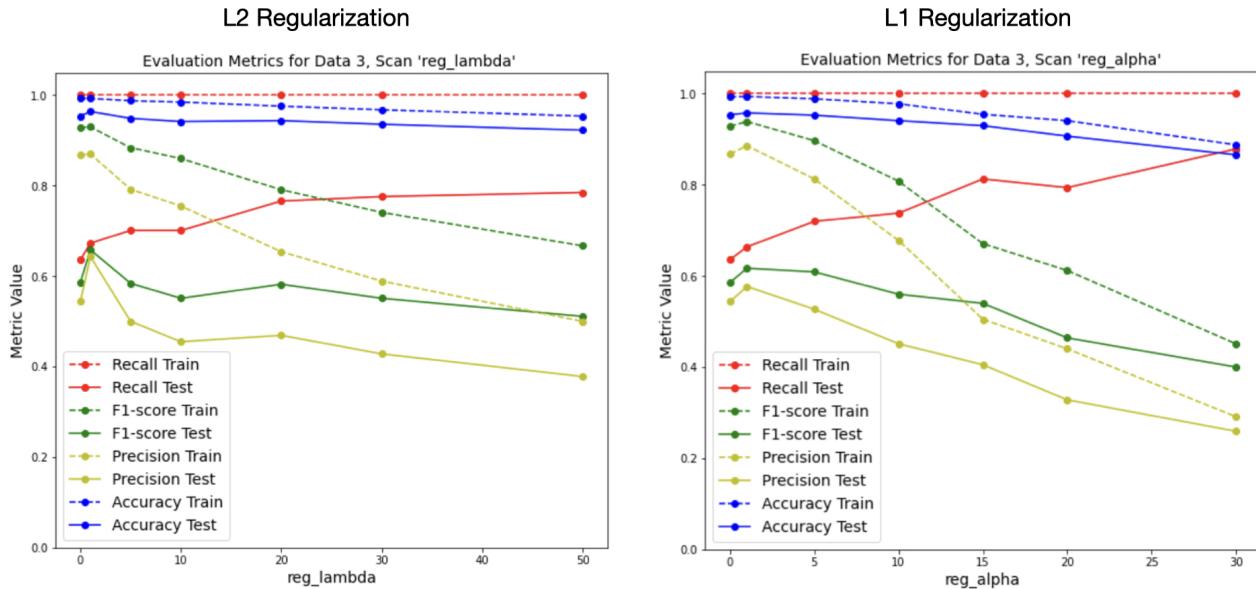
- max\_depth: Log loss and metrics



- learning\_rate: Log loss and metrics



- L1 and L2 Regularization metrics



- Optimum parameters for max\_depth=5:
  - scale\_pos\_weight = 20,
  - n\_estimators = 125,
  - max\_depth = 5,
  - min\_child\_weight = 3,
  - gamma = 0,
  - learning\_rate = 0.20,
  - max\_delta\_step = 0,
  - reg\_lambda = 0,
  - reg\_alpha = 5,
  - subsample = 1,
  - colsample\_bytree = 0.7

### Model 9: Optimized Model at max\_depth=4

- Same optimization approach is followed for max\_depth=4.
- Optimum parameters for max\_depth=4:
  - scale\_pos\_weight = 4.5,
  - n\_estimators = 125,
  - max\_depth = 4,
  - min\_child\_weight = 3,
  - gamma = 0,
  - learning\_rate = 0.20,

- max\_delta\_step = 0,
- reg\_lambda = 1,
- reg\_alpha = 0,
- subsample = 1,
- colsample\_bytree = 1

### **Model 10: Optimized Model at max\_depth=6**

- Same optimization approach is followed for max\_depth=6.
- Optimum parameters for max\_depth=6:
  - scale\_pos\_weight = 20,
  - n\_estimators = 80,
  - max\_depth = 6,
  - min\_child\_weight = 3,
  - gamma = 0,
  - learning\_rate = 0.25,
  - max\_delta\_step = 4,
  - reg\_lambda = 1,
  - reg\_alpha = 0,
  - subsample = 1,
  - colsample\_bytree = 1

### **Best Model for Data 3**

- Model 9, optimized at max\_depth=4, is the best model for Data 3.
  - Maximum recall
  - Moderate precision
  - Minimum overfitting

The table below compares the performance of models for Data 3:

Params		precision	recall	f1	accuracy	auc
<b>Model 1 Train</b>						
<b>Test</b>	1.000	1.000	1.000	1.000	1.000	1.000
<b>Model 2 Train</b>						
<b>Test</b>	0.926	0.467	0.621	0.971	0.941	
<b>Model 3 Train</b>						
<b>Test</b>	0.990	1.000	0.995	1.000	1.000	
<b>Model 7 Train</b>						
<b>Test</b>	0.677	0.607	0.640	0.965	0.916	
<b>Model 9 Train</b>						
<b>Test</b>	0.956	1.000	0.977	0.998	1.000	
<b>Model 10 Train</b>						
<b>Test</b>	0.645	0.645	0.645	0.964	0.922	
<b>Model 7 Test</b>						
<b>Test</b>	0.771	1.000	0.871	0.986	1.000	
<b>Model 9 Test</b>						
<b>Test</b>	0.535	0.720	0.614	0.954	0.923	
<b>Model 9 Test</b>						
<b>Test</b>	0.719	1.000	0.836	0.982	1.000	
<b>Model 10 Test</b>						
<b>Test</b>	0.554	0.720	0.626	0.956	0.916	
<b>Model 10 Test</b>						
<b>Test</b>	0.900	1.000	0.947	0.995	1.000	
<b>Model 10 Test</b>						
<b>Test</b>	0.626	0.701	0.667	0.964	0.921	

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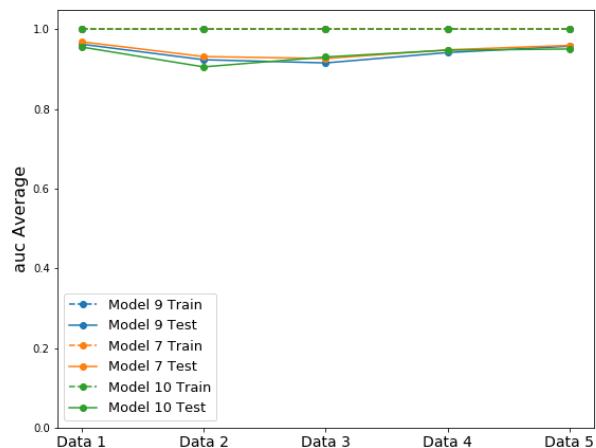
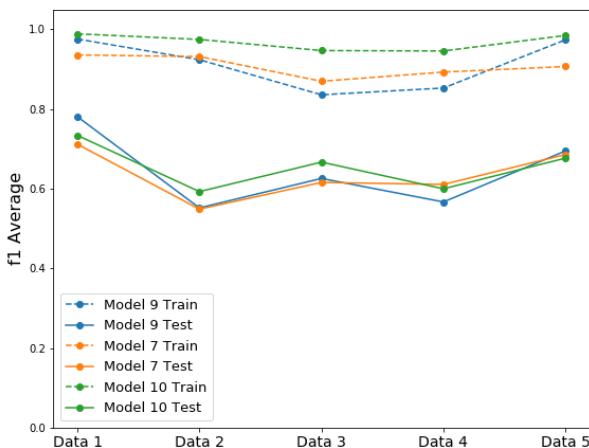
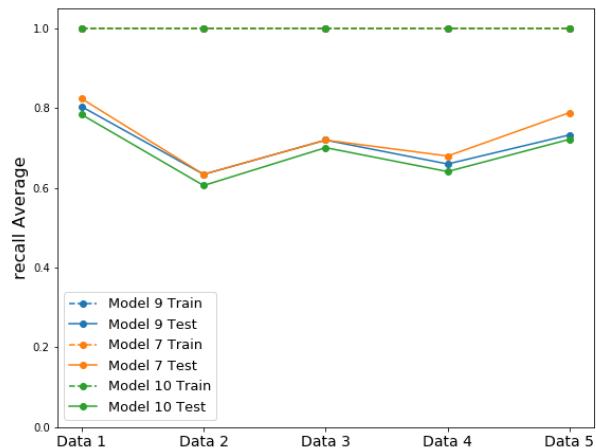
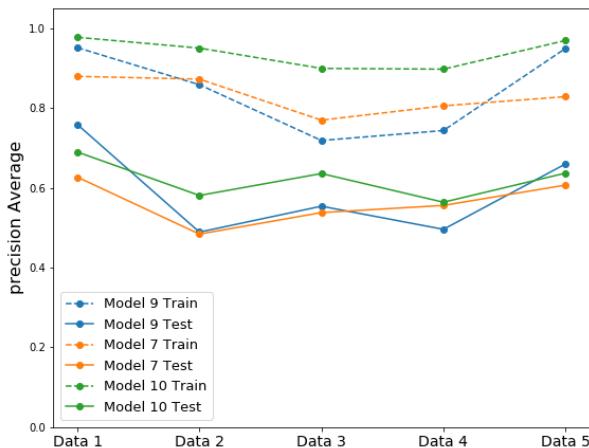
## Model Performance on All Datasets

I have applied the optimumum models on all five datasets.

- Model 7 at max\_depth=5
- Model 9 at max\_depth=4
- Model 10 at max\_depth=6

Note: I also tried to tune the parameters to see if I can get a model performs equally good, better, on all data files. But no success.

Metrics graphs for comparison:



Overall the performance of the models are similar, especially recall.

Model 9 (max\_depth=4):

- Previously Selected performance for data 3
- Overfitting is least on Data 3

Model 7 (max\_depth=5):

- Performance is similar to Model 9
- More smooth performance on all datasets

Model 10 (max\_depth=6):

- Highest metrics
- But overfitting is slightly larger

Selected model: Model 7

## Final Model

Model 7 is the best performing, when all datasets are considered.

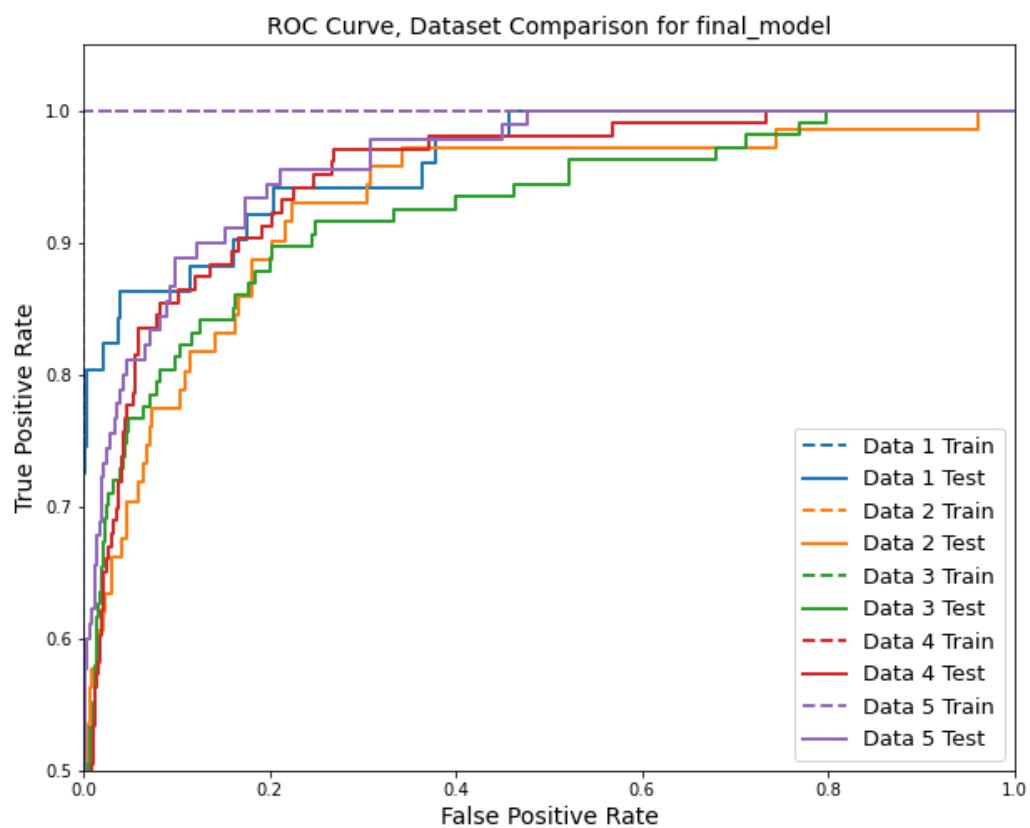
- Final Model parameters:

- scale\_pos\_weight = 20,
- n\_estimators = 125,
- max\_depth = 5,
- min\_child\_weight = 3,
- gamma = 0,
- learning\_rate = 0.20,
- max\_delta\_step = 0,
- reg\_lambda = 0,
- reg\_alpha = 5,
- subsample = 1,
- colsample\_bytree = 0.7

- Metrics table:

		Sample	precision	recall	f1	accuracy	auc
<b>Data</b>							
<b>Data 1</b>	Train	0.8700	1.0000	0.9300	0.9940	1.0000	
<b>Data 1</b>	Test	0.6410	0.8040	0.7130	0.9770	0.9610	
<b>Data 2</b>	Train	0.8750	1.0000	0.9330	0.9940	1.0000	
<b>Data 2</b>	Test	0.5060	0.6200	0.5570	0.9660	0.9280	
<b>Data 3</b>	Train	0.7710	1.0000	0.8710	0.9860	1.0000	
<b>Data 3</b>	Test	0.5350	0.7200	0.6140	0.9540	0.9230	
<b>Data 4</b>	Train	0.8060	1.0000	0.8930	0.9870	1.0000	
<b>Data 4</b>	Test	0.5560	0.6800	0.6110	0.9550	0.9490	
<b>Data 5</b>	Train	0.8290	1.0000	0.9070	0.9860	1.0000	
<b>Data 5</b>	Test	0.6070	0.7890	0.6860	0.9450	0.9600	
<b>Average</b>	Train	0.8302	1.0000	0.9068	0.9894	1.0000	
<b>Average</b>	Test	0.5690	0.7226	0.6362	0.9594	0.9442	

- ROC curve:



### Class 0 predictions for Final Model

The table below shows the prediction metrics of the final model for the still operating companies (class 0).

Data #	sample	precision	recall	f1
Data 1	Train	1.00	0.99	1.00
Data 1	Test	0.99	0.98	0.99
Data 2	Train	1.00	0.99	1.00
Data 2	Test	0.99	0.98	0.98
Data 3	Train	1.00	0.99	0.99
Data 3	Test	0.98	0.97	0.98
Data 4	Train	1.00	0.99	0.99
Data 4	Test	0.98	0.97	0.98
Data 5	Train	1.00	0.99	0.99

Data #	sample	precision	recall	f1
Data 5	Test	0.98	0.96	0.97

## Best common predictors

These three attributes are good predictors for all five datasets.

- X27: profit on operating activities / financial expenses
- X34: operating expenses / total liabilities
- X5: [(cash + short-term securities + receivables - short-term liabilities) / (operating expenses - depreciation)] \* 365

## Interpretation of Results

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5-year Period (Data 1):

- Model correctly identifies the 80.4% of the true bankrupt companies, which will bankrupt 5 years later. (recall)
- Among the model predicted bankruptcy companies, 64.1% of them are true bankrupt companies, which will bankrupt 5 years later. (precision)
- The Harmonic Mean of Precision and Recall (f1-score) is 71.3%.

4-year Period (Data 2):

- Model correctly identifies the 62.0% of the true bankrupt companies, which will bankrupt 4 years later. (recall)
- Among the model predicted bankruptcy companies, 50.6% of them are true bankrupt companies, which will bankrupt 4 years later. (precision)
- The Harmonic Mean of Precision and Recall (f1-score) is 55.7%.

3-year Period (Data 3):

- Model correctly identifies the 72.0% of the true bankrupt companies, which will bankrupt 3 years later. (recall)
- Among the model predicted bankruptcy companies, 53.5% of them are true bankrupt companies, which will bankrupt 3 years later. \* The Harmonic Mean of Precision and Recall (f1-score) is 61.4%.

2-year Period (Data 4):

- Model correctly identifies the 68.0% of the true bankrupt companies, which will bankrupt 2 years later. (recall)
- Among the model predicted bankruptcy companies, 55.6% of them are true bankrupt companies, which will bankrupt 2 years later. (precision)
- The Harmonic Mean of Precision and Recall (f1-score) is 61.1%.

1-year Period (Data 5):

- Model correctly identifies the 78.9% of the true bankrupt companies, which will bankrupt 1 years later. (recall)
- Among the model predicted bankruptcy companies, 60.7% of them are true bankrupt companies, which will bankrupt 1 years later. (precision)
- The Harmonic Mean of Precision and Recall (f1-score) is 68.6%.

On Average:

- Model correctly identifies the 72.3% of the true bankrupt companies. (recall)
- Among the model predicted bankruptcy companies, 56.9% of them are true bankrupt companies. (precision)
- The Harmonic Mean of Precision and Recall (f1-score) is 63.6%.

Class 0 predictions:

- Model correctly identifies the ~97% of the true still operating companies. (recall, class 0)
- Among the model predicted still operating companies, ~98% of them are true still operating companies. (precision, class 0)
- The Harmonic Mean of Precision and Recall (f1-score, class 0) is ~98%.

## Conclusion

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I had three main challenges in this project:

### 1. Class Imbalance:

- Resolved.
- Balancing the sample increased the recall and so decreased the precision. The balance sample has moderate evaluation scores. See Model 2 for Data 3.
- However overfitting didn't improve much.

### 2. Low recall score:

- I managed to improve recall significantly for all datasets. For instance, Data 3 recall score improved from 0.467 to 0.720.
- I couldn't go for higher recall value, because the precision was decreasing dramatically (below 0.5). The recall and precision are inversely proportional.

### 3. Large overfitting:

- I did decrease the overfitting, but not on desired level.
- I tuned parameters which are effective on overfitting, and find the optimum designs that produces low overfitting, large recall and moderate precision.
- However, I couldn't enforce larger reduction in overfitting, since it causes the precision go below 0.5. which is the random guess probability.

Overall, my model correctly identifies

- 72.3% of the true bankrupt companies
- 97% of the true still operating companies

## Future Work

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- Create separate final models for each dataset; not just one final model that applies on all.
- Search for alternative Classifier methods/tools.
- Simplify/shorten functions that are created during the project. They have repeating codes.

## Releases

No releases published  
[Create a new release](#)

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## Packages

No packages published  
[Publish your first package](#)

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## Languages

- Jupyter Notebook 99.7%
- Python 0.3%