A robust machine learning approach for credit risk analysis of large loan level datasets using deep learning and extreme gradient boosting

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BANK OF GREECE
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The views expressed in this paper are those of the authors and not necessarily those of Bank of Greece

Credit Risk Analysis Tool

In a nutshell

Novel Rating System for Greek banks business portfolios

Proactive monitoring

Economic assessment

Modeling technique

- Extreme Gradient Boosting
- Deep Neural Networks

Main Drivers

- Company Financial Ratios
- Macroeconomic factors

Implementation

- Corporate and SME loans of the Greek banking system, from the supervisory database of the Central Bank of Greece

Credit Risk Analysis

Machine and Deep learning techniques

- "Learn" without being explicitly programmed
- Unveiling new determinants and unexpected forms of dependencies among variables.
- Tackling non linear relationships.

- Use of ML and Deep Learning are favored by the technological advances and the availability of financial sector data.
- Supervisory authorities should keep up with the current developments.

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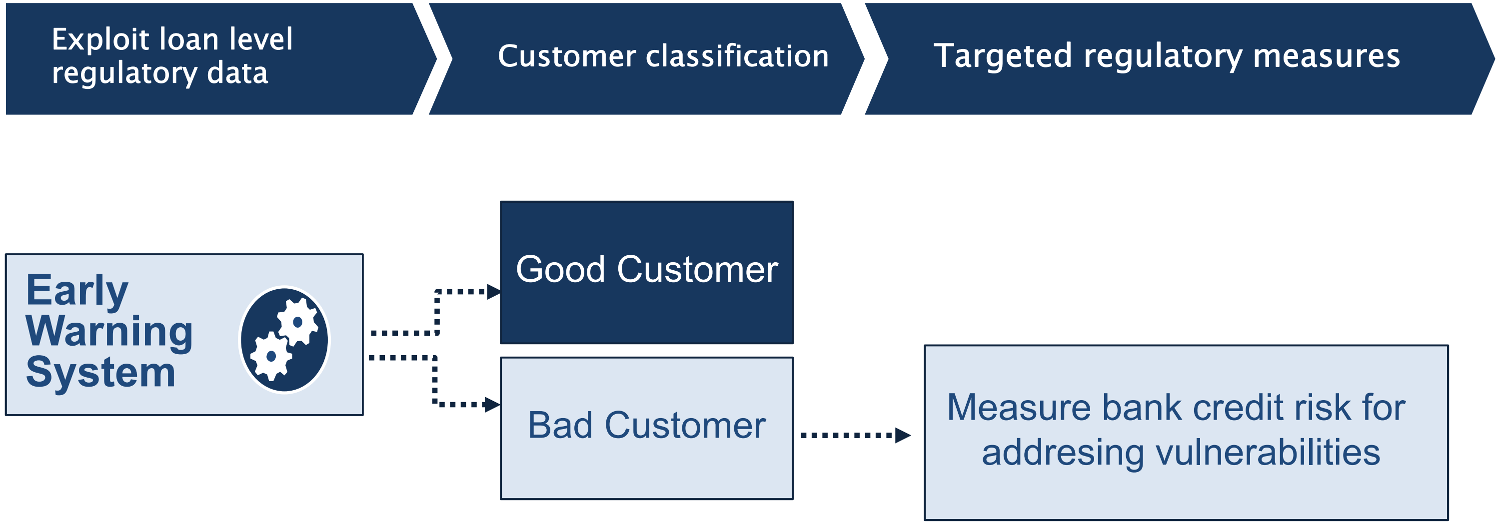
Bank of Greece – Regulatory Purpose



Credit Risk Analysis – Big Data

Anacredit project European Central bank

Reporting threshold 25.000 euro

AnaCredit data set

	Tabelle / Datencluster	Frequenz	# Attribute
1	Counterparty reference data	once[1]	23
2	Instrument data	once[1]	24
3	Financial data	monthly	14
4	Counterparty instrument data	once[1]	1
5	Joint liabilities data	monthly	1
6	Accounting data	quarterly	16
7	Protection received data	once[1]	10
8	Instrument-protection received data	monthly	2
9	Counterparty risk data	quarterly	1
10	Counterparty default data	monthly	2
	Identifier		7

Totals: 88 / 95

New attributes:
- Head office undertaking
- Immediate parent undertaking identifier

Deleted attributes:
- Type of entity
- Address: street number
- Address: city area/district
- Correlation product
- Annual percentage rate of charge
- Convenience credit
- Extended credit
- Eligibility of protection for credit risk mitigation

Source: ECB regulation on the collection of granular credit and credit risk data as of May 18th, 2016

- AnaCredit will be a new dataset with detailed information on individual bank loans in the euro area.
- The project was initiated in 2011 and data collection is scheduled to start in September 2018.

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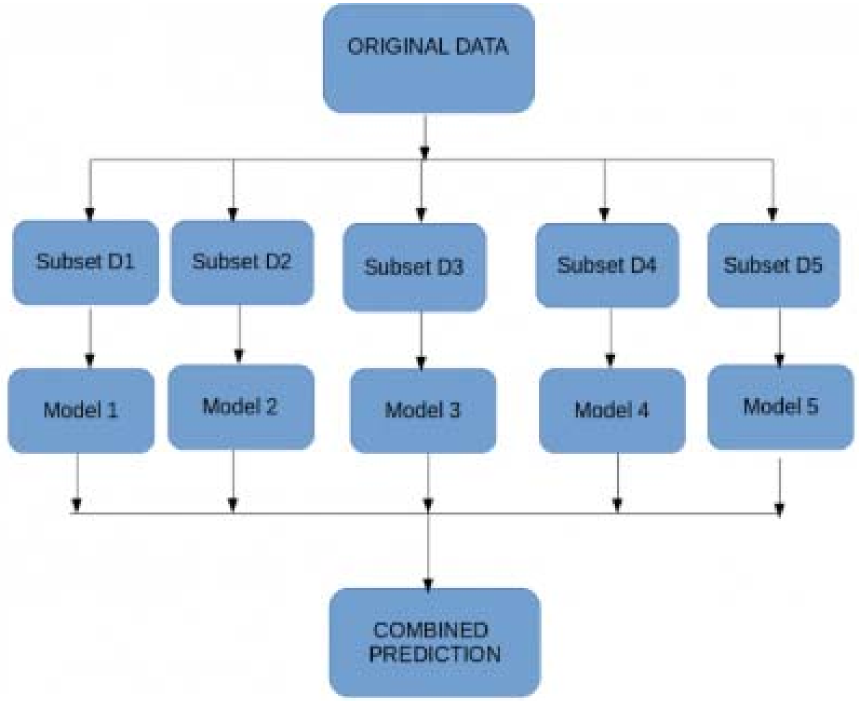
Bagging – Different models vote for the result



source: Analytics Vidhya

- Multiple subsets are created from the original dataset, selecting observations with replacement and a base model (weak model) is created on each of these subsets.
- The models run in parallel and are independent of each other.
- The final predictions are determined by combining the predictions from all the models.
- Random Forests are common employed bagging techniques.

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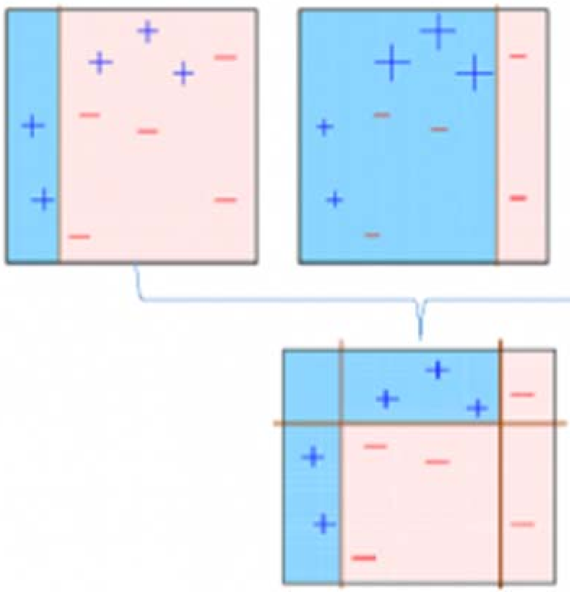
Boosting – Each model learns from the errors of the previous



source: Analytics Vidhya

- A base model is created based on a subset of the original dataset which is used to make predictions on the whole dataset.
- Errors are calculated and observations which are incorrectly predicted, are given higher weights (large plus signs).
- Another model is created which tries to correct the errors from the previous model.
- Similarly, multiple models are created, each correcting the errors of the previous model.
- The final model (strong learner) is the weighted mean of all the models (weak learners).

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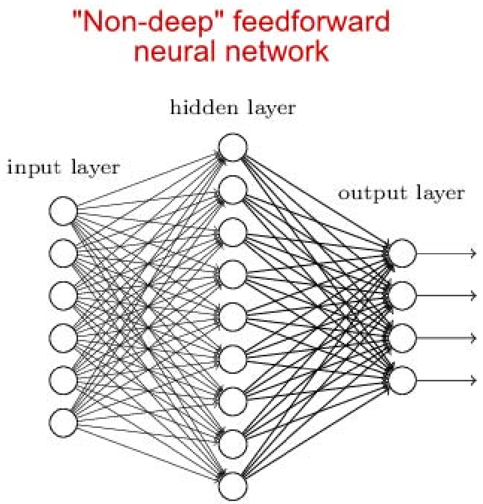
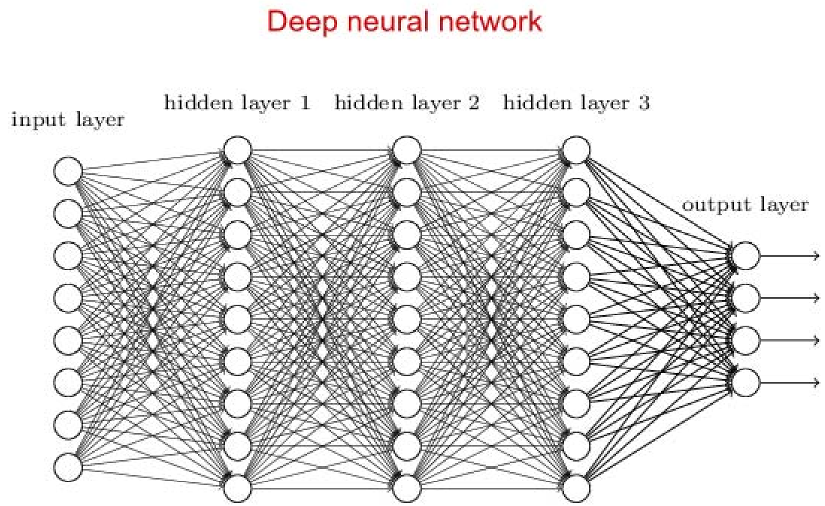
Deep Neural Networks-Unlimited potential for Architectures





Deep neural network is simply a feedforward network with many hidden layers. It has the following advantages compared to one layer networks ("shallow")

- A deep network needs less neurons than a shallow one
- A shallow network is more difficult to train with our current algorithms (e.g. it has more nasty local minima, or the convergence rate is slower)

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Deep Neural Networks-Unlimited potential for Architectures

This methodology provides the opportunity of creating a large combination of different structures based on

- Number of layers,
- Selection of activation function
- Number of perceptrons
- Normalization layers
- Dropout adjustments

Which can be employed in the optimization process

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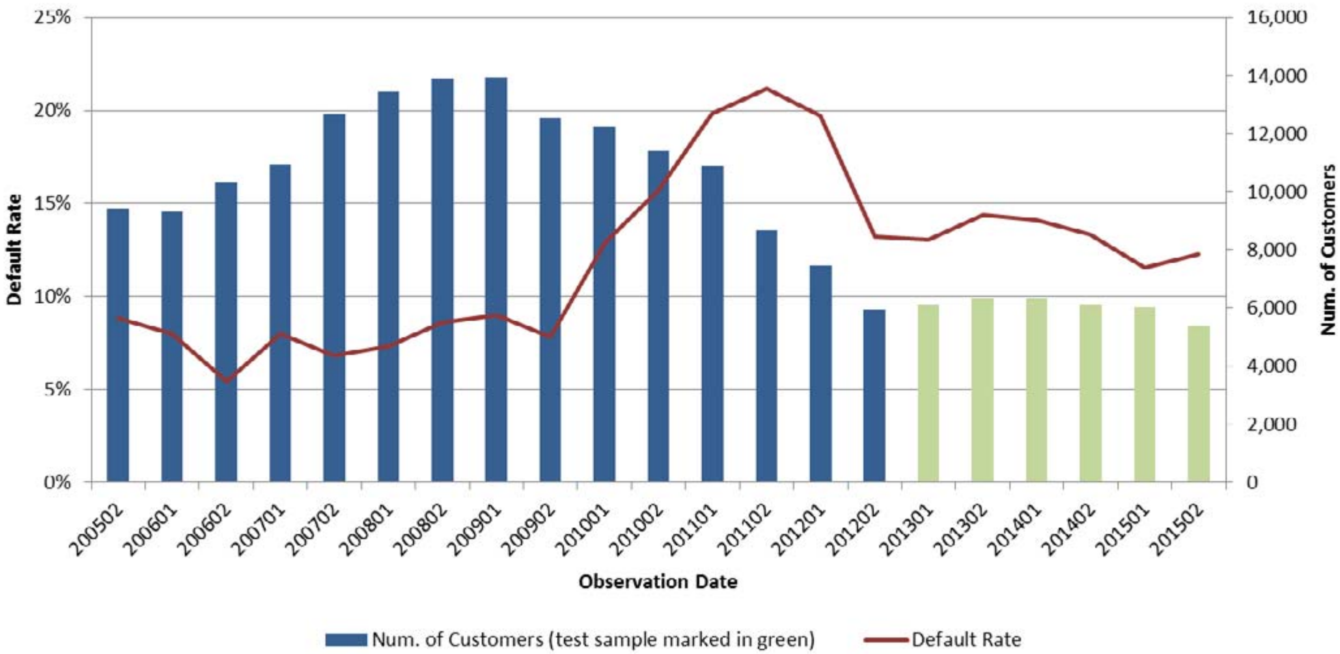
Problem at hand



- We have collected loan level information on Corporate and SME loans of the Greek banking system, from the supervisory database of the Central Bank of Greece.
- A loan is flagged as delinquent if it is either 90 days past due or it gets rated as delinquent based on each bank's internal rating rules.
- The forecast horizon for a default event is 1 year whereas the variables employed include macro data and company specific financial ratios.

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Many Predictor Candidates - Curse of dimensionality

Boruta (aka Leshy): Slavik deity dueling in forests. 1906 illustration

- We employ **Boruta algorithm** for tackling the dimensionality issue. This is sequential Random Forest based algorithm which removes non relevant variables decreasing the dimensionality space.

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Many Predictor Candidates - Curse of dimensionality

Boruta Algorithm – steps:

- First, it adds randomness to the given dataset by creating shuffled copies of all features (shadow features).
- Then, it fits a Random Forest model (bagging model) on the extended dataset and evaluates the importance of each feature based on Z score.
- In every iteration, it checks whether a real feature has a higher importance than the best of its shadow features, and constantly removes features which are deemed unimportant

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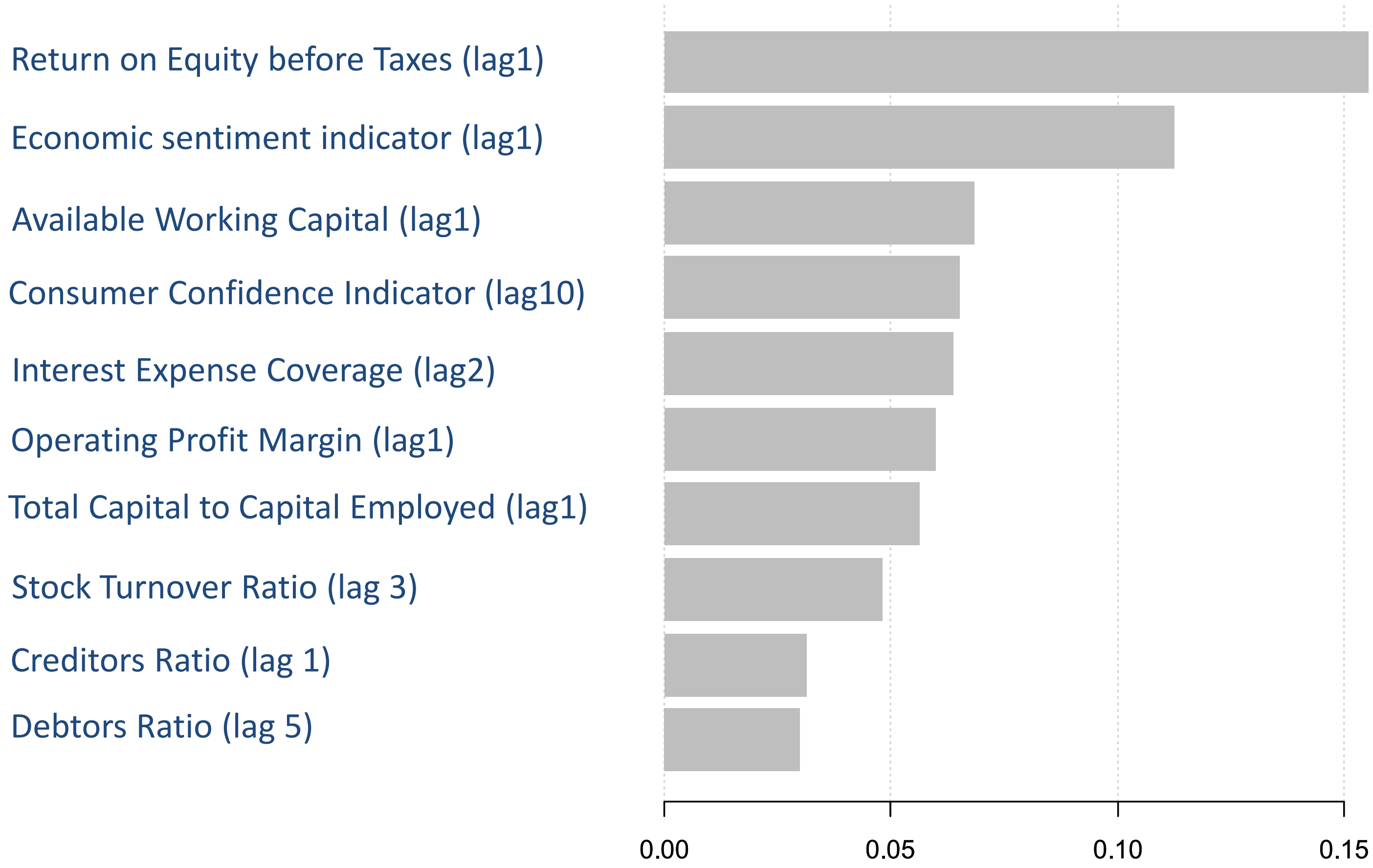
Extreme Gradient Boosting
Variable Importance

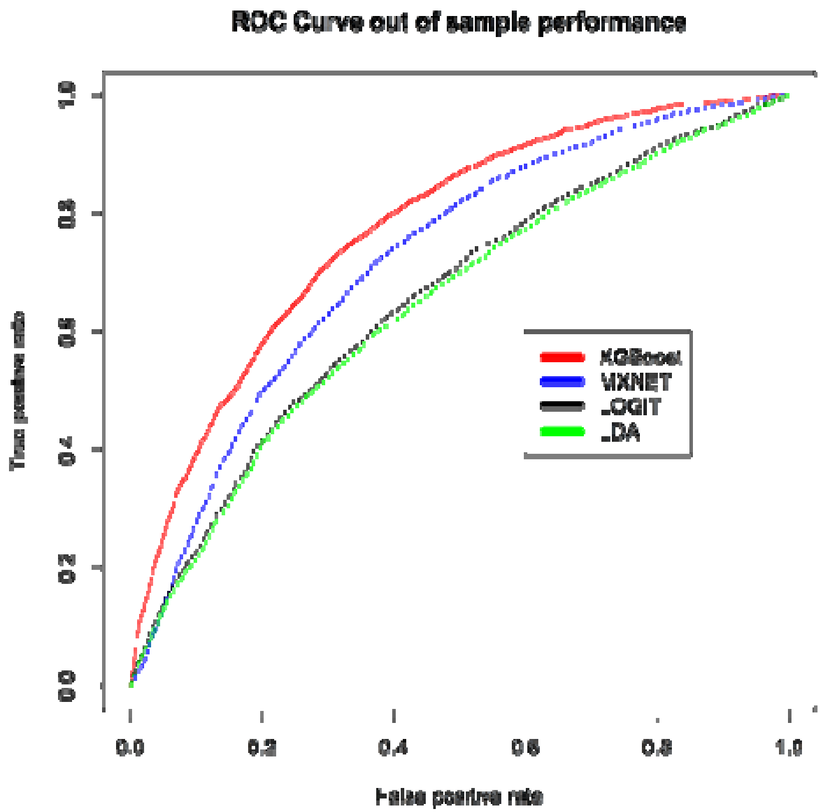


Extreme Gradient Boosting
Classification Accuracy

Classification Accuracy Model Comparison		Table 1
	KS	AUROC
Logit	24%	66%
LDA	23%	65%
XGBoost	42%	78%
MXNET	35%	72%

Classification Accuracy Metrics: Kolmogorov - Smirnov (KS), Area Under ROC curve (AUROC).

XGBoost and **MXNET** algorithms provide better classification accuracy compared to traditional classification methods such as Logistic Regression and Linear Discriminant analysis.



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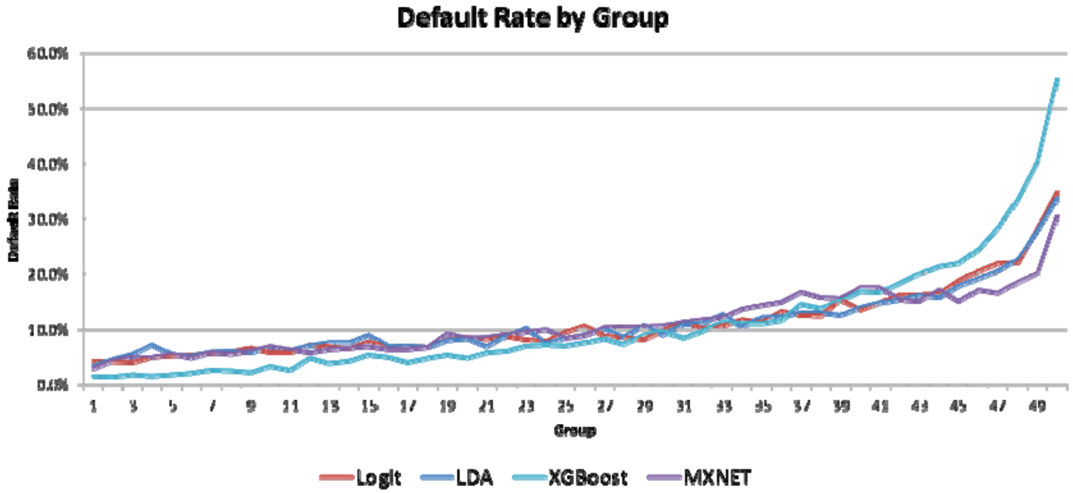
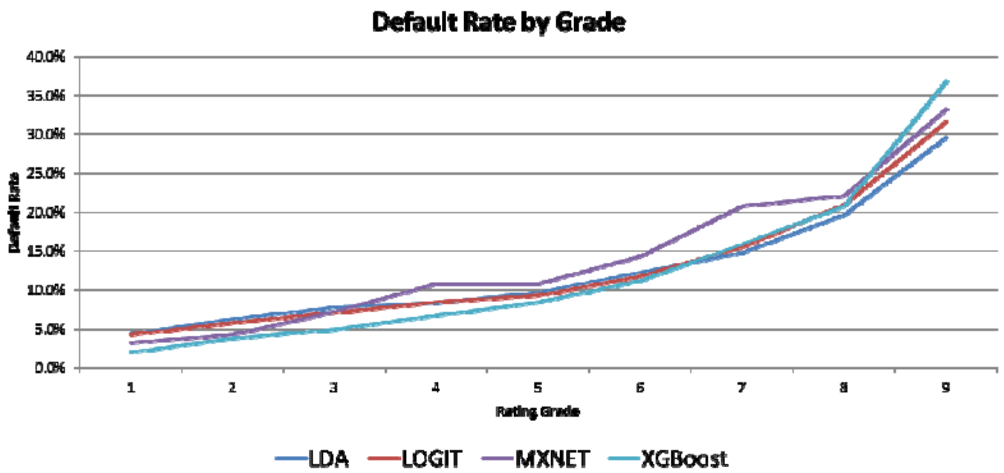
Calibrating a Rating system



Initial credit rating segmentation in 50 grades



Final credit rating segmentation in 9 grades

Deep Neural Networks

Rating System Performance

Performance Metrics Credit Rating System		Table 2
	SSE	BRIER
Logit	4.3%	11.3%
LDA	4.8%	11.4%
XGBoost	0.2%	10.1%
MXNET	0.6%	11.0%

Rating System Calibration Metrics: Sum of Square Error (SSE), Brier's score (BRIER).

Estimated and Actual default frequency metrics			Table 3
	Estimated Probability of Default	Observed Default Rate (Out of sample)	Observed Default Rate (In sample)
Logit	8.20%	13.10%	11.00%
LDA	7.80%		
XGBoost	13.50%		
MXNET	15.00%		

Estimated Probability of Default vs observed Default Rate in out-of-sample and in-sample population

- Based on SSE and Brier score the MXNET and XGBOOST rating systems perform better than Logistic Regression and Linear Discriminant analysis.
- The estimated PDs for MXNET and XGBOOST are closer to the observed default rates.

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Our Contribution

- ✓ Extensive exploration of advanced statistical techniques
- ✓ An automated algorithm for tackling dimensionality issues
- ✓ Application to a regulatory large size dataset
- ✓ Robust validation and Performance Measures
- ✓ Large potential for application in large datasets (Anacredit)

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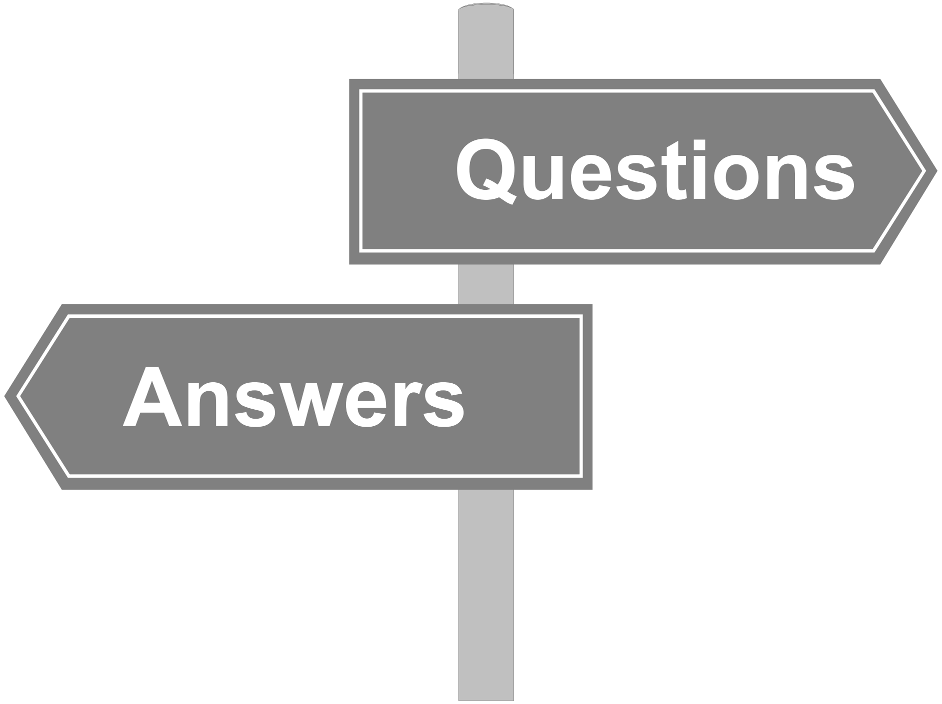
Q&A



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Thank you!