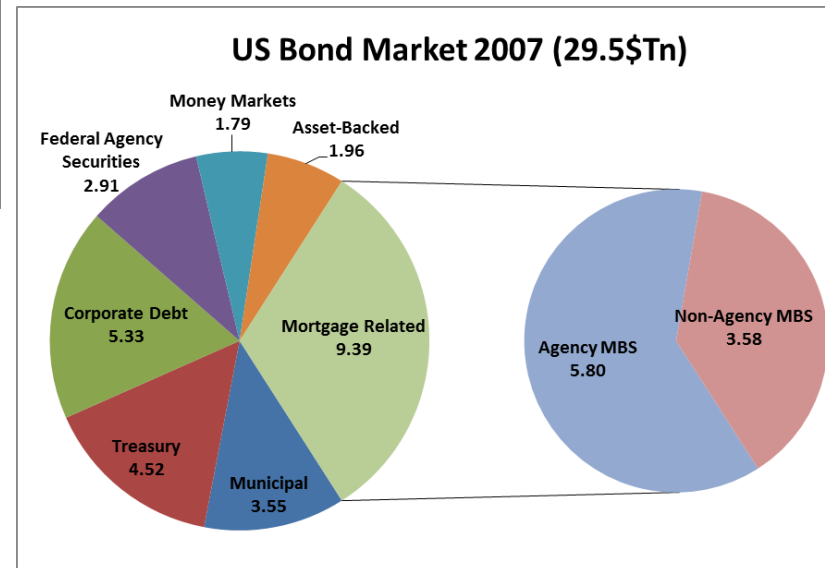
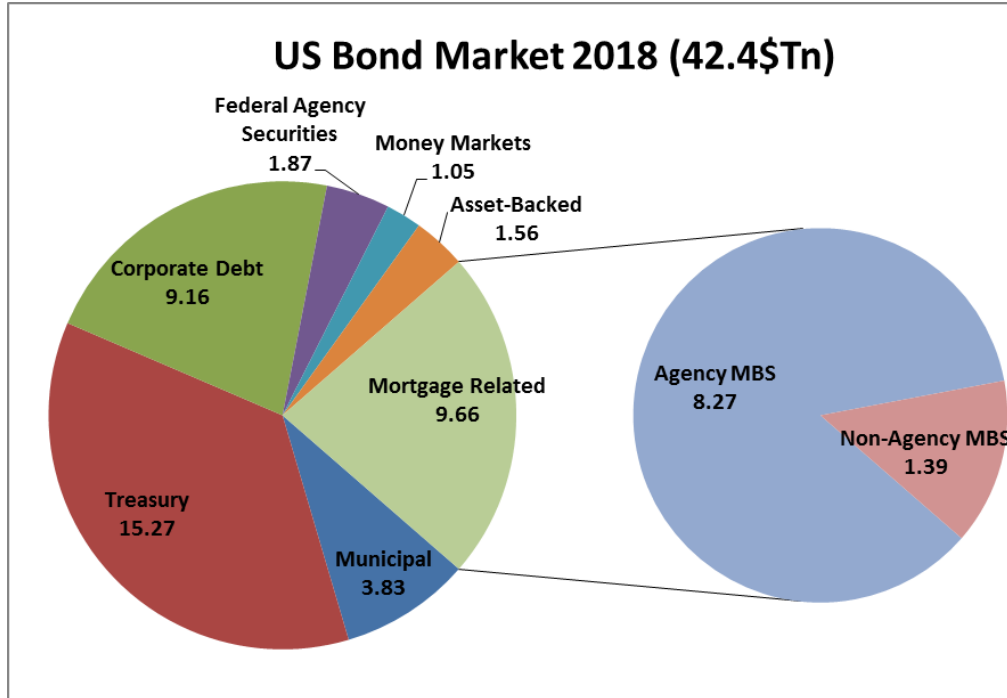


Neural Network Model of Mortgage-Backed Security Prepayments

MATHEMATICAL MODELLING SEMINAR

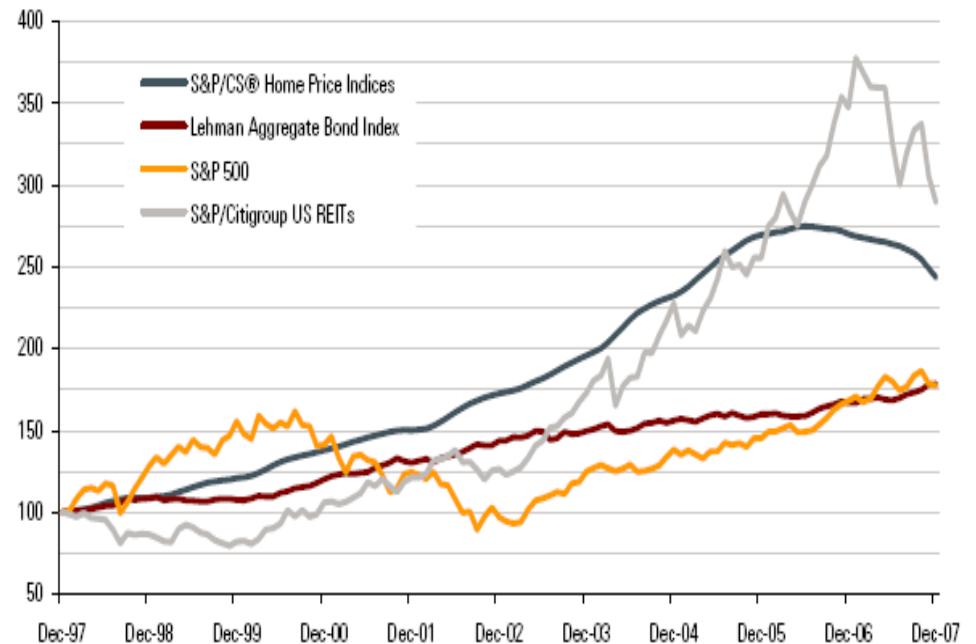
Miklós Vörös, MSCI, Nov 2019

US Bond Market

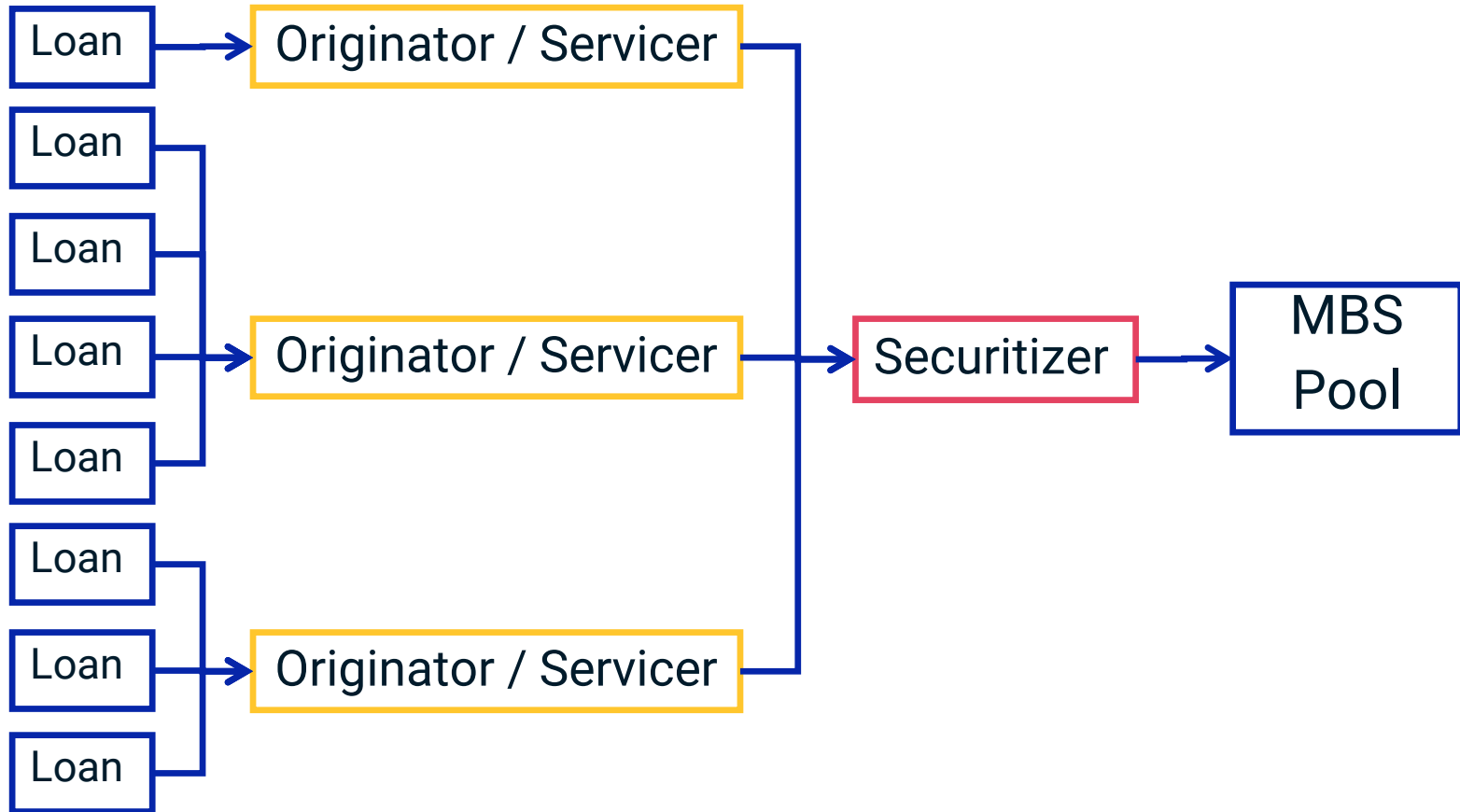


Why Bother With Housing?

Asset	Return	Volatility
Housing	9.31%	2.77%
Bonds	5.97%	3.47%
Stocks	5.91%	14.72%

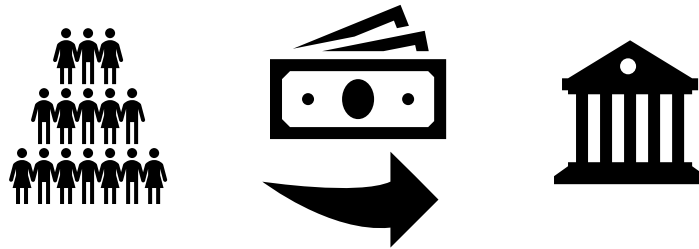


► Mortgage-Backed Securities (MBS)



Main Risk: Prepayment

Unscheduled Principal Payment



May come from:

- Turnover
- Refinancing
 - Rate, term
 - Cash out
- Default
- Curtailment

Might be affected by:

- General hardship
- Lock out
- Underwriting standards
- Psychology of the individual
- Media effect
- Malicious intent

► Beyond Data



1% Low Start Rate

Stated Income

No Documentation Loans

100% Finance Available

Interest Only Loans

Debt Consolidation

SE HABLA ESPAÑOL

► Modeling Objective

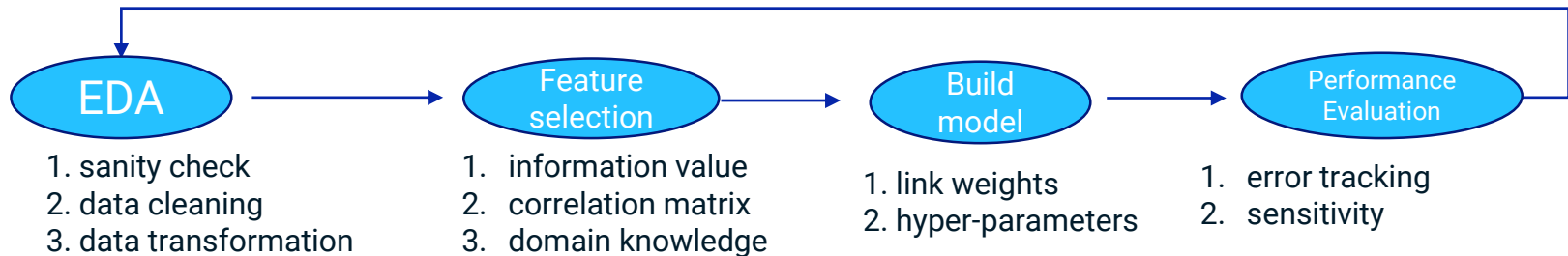
Forecast monthly prepayment rate for Agency RMBS pools

- Measure: monthly SMM - Single Monthly Mortality Rate
- Historical periods: 2003-2015 (train, validate), 2016-2018 (test)
- Raw data:
 - Mortgage characteristics (30 raw attributes from eMBS ~25GB)
 - Macroeconomic and Market conditions:
 - Home Price Index (State level)
 - Mortgage rate
 - Unemployment rate

Machine Learning in Finance

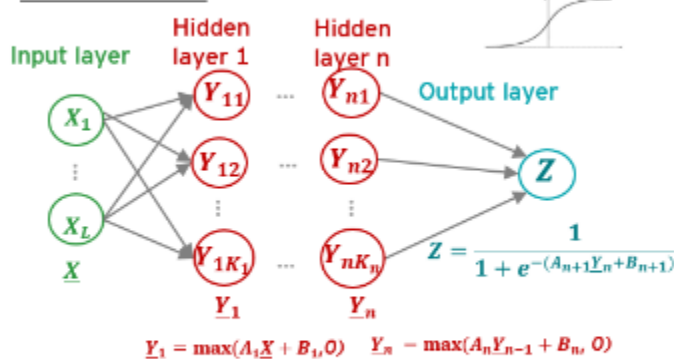
- **Consumer credit risk models via Machine-Learning Algorithms (Dr. Andrew Lo, 2010)**
Using machine-learning model for consumer credit delinquency and default
Generalized classification and regression trees
Accurately forecasted credit events 3 to 12 months in advance
- **Risk and risk management in credit card industry (Dr. Andrew Lo, 2016)**
Analyzed a large dataset consisting of credit card data from six large banks.
Decision trees and random forests model perform better than logistic regression at short time horizon
- **Deep learning for mortgage risk (Dr. Kay Giesecke, 2015-2018)**
Using deep neural network to model mortgage prepayment, delinquency and foreclosure
Loan level data
Compared NNM with a logit model
- **Machine Learning and Alternative Data Approach to Investing (JPM,2017)**
Comprehensive guide for applying machine learning to solve financial problems

Modeling Process



Deep neural network model

Architecture*

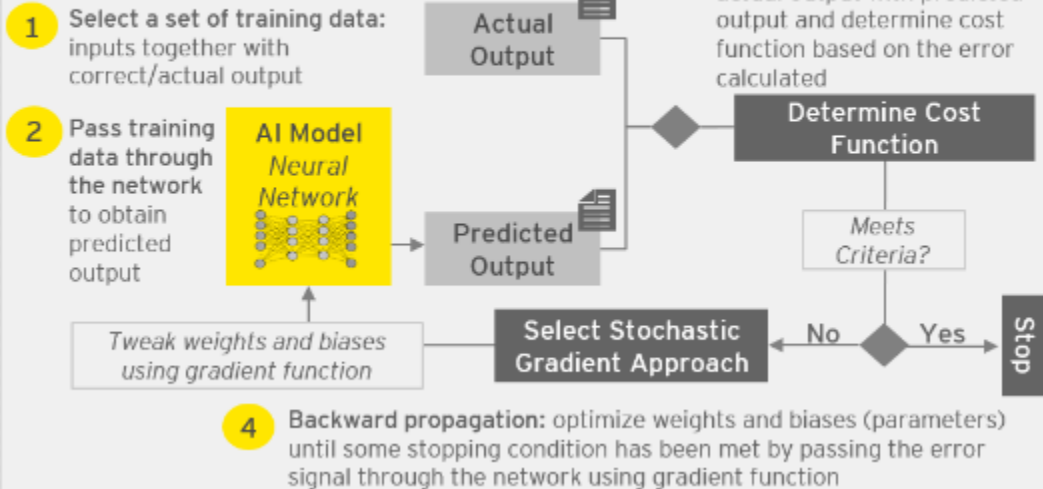


Values of hidden layers are generated by activation functions with previous layers as inputs, and weights and biases as parameters

*Example of a Neural Network architecture

○ Node

Model training



Model Setup

The MSCI Machine Learning Model:

- Fully connected, feed forward NN, with multiple hidden layers
- Activation: ReLU
- Optimization: ADAM
- Regularization: dropout, L2, max. norm., batch norm.
- Ensemble: Bagging, averaging
- Hyper-parameter optimization: Grid search

Training:

10 - 90% train, valid split
~3 hours, 150 hours total

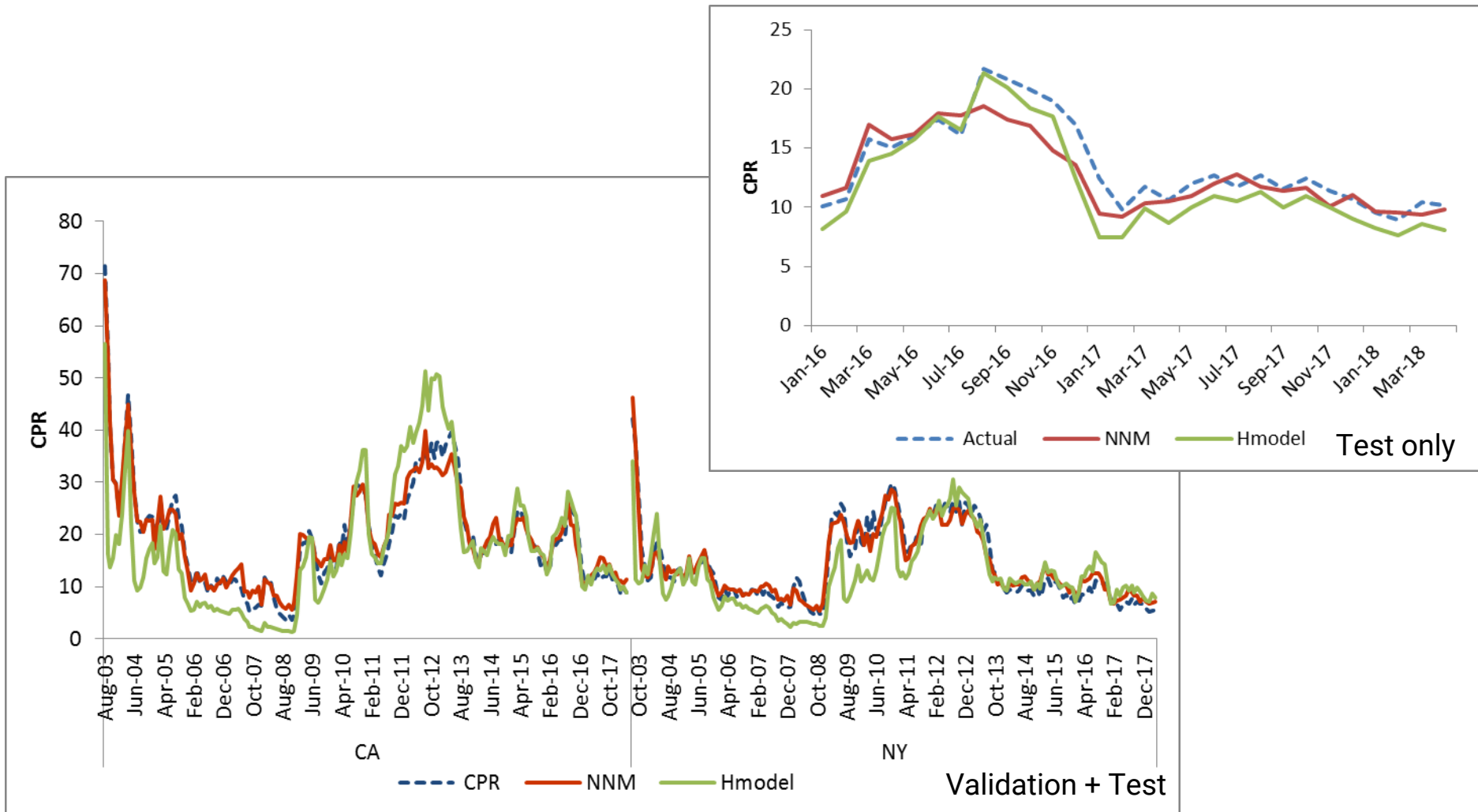
GTX 1080 Ti
128GB memory

Main hyper-parameters – and optimal values:

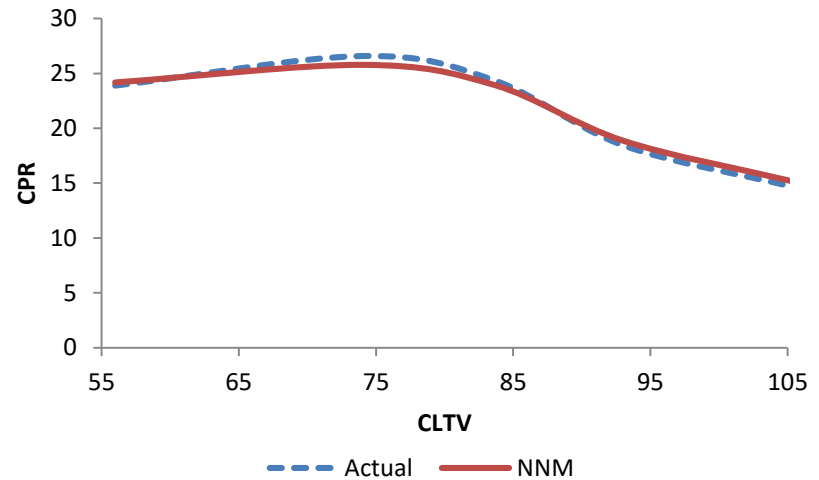
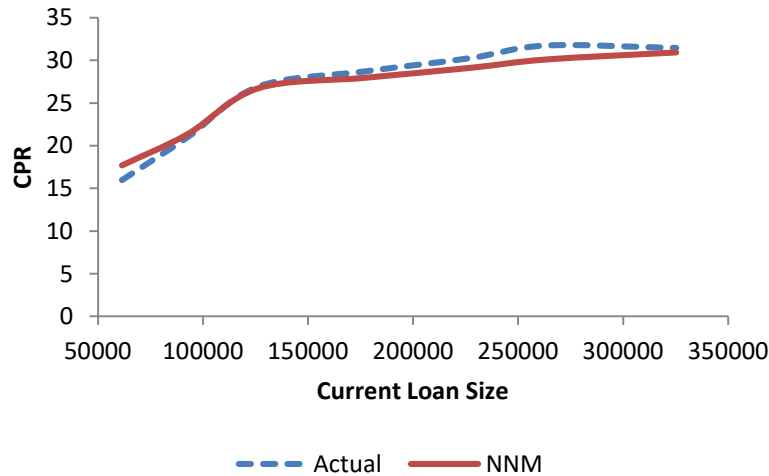
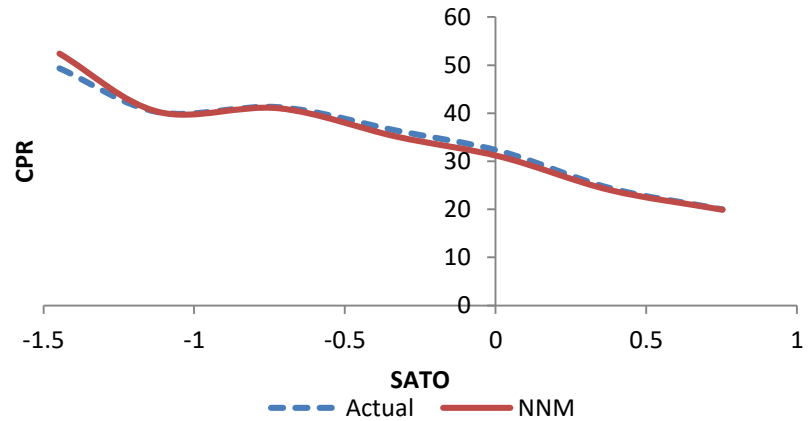
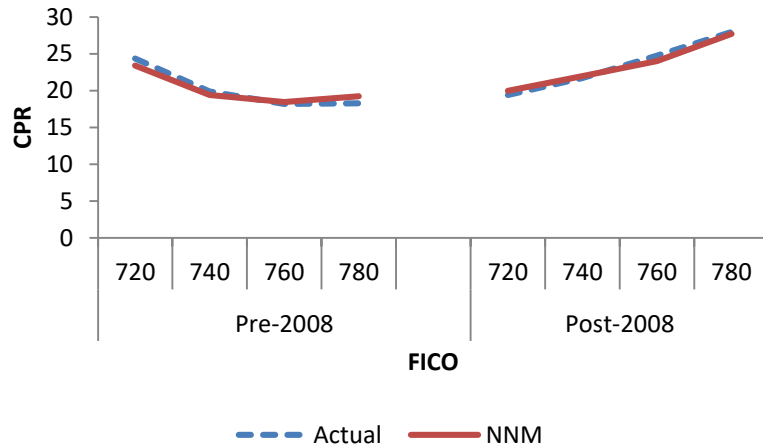
- Number (5) of hidden layers (512, 256, 125, 32, 8)
- Batch size (1024)
- Max-norm constraint (0.5)
- Dropout rate (0.4)
- Activation function (ReLU)

Error Tracking

MSCI ML model and legacy model vs. observed annual prepayment speeds



Effect of Risk Factors



Conclusion

Deep neural network models can be used to predict MBS prepayments

The ML model:

- Is able to capture complex prepayment patterns and signals
- Can be built much faster than a manual model
- May also provide valuable insights for manual model building
- Domain knowledge can still contribute (feature selection)

► Acknowledgements

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Ernst & Young

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- Fei Teng, Senior Quantitative Analysts, Quantitative Advisory Services
- Siyu Lin, Senior Quantitative Analysts, Quantitative Advisory Services
- Henry Li, Executive Director, Quantitative Advisory Services

Publications:

- 2018, D., Zhang, et. al., [Agency MBS Prepayment Model Using Neural Networks](#), Journal of Structured Finance
- [Blogpost](#) on msci.com

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