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Quantum Computing for Credit Risk

Material:

- Presentations PDF
- Exercises in Excel, R, Python, Jupyterlab y Tensorflow

Duration: 50 h

Price: 11.000 €

COURSE OBJECTIVE

Credit risk modeling course using artificial intelligence and quantum computing, among many other topics: credit scoring tools, modeling of PD, LGD and EAD parameters of the advanced IRB approach of Basel III, credit risk methodologies for IFRS 9 impairment models, stress testing models of credit risk and economic capital.

Among other topics, quantum computing, quantum circuits, important quantum algorithms, quantum mechanics, quantum error and correction, and quantum machine learning are exposed.

Machine and deep learning are used to build powerful credit scoring and behavior scoring tools, as well as to estimate and calibrate risk parameters and stress testing.

A module on advanced data processing is exposed, explaining among other topics: sampling, exploratory analysis, outlier detection, advanced segmentation techniques, feature engineering and classification algorithms.

The course explains the recent final reforms of Basel III regarding the new standard approach and Advanced IRB, IFRS 9 related to credit risk and the new guidelines on estimation of PD and LGD and treatment of exposures in default of EBA.

Predictive machine learning models are shown such as: decision trees, neural networks, Bayesian networks, Support Vector Machine, ensemble model, etc. And in terms of neural networks, feed forward, recurrent RNN, convoluted CNN and adversarial Generative architectures are exposed. In addition, Probabilistic Machine Learning models such as Gaussian processes and Bayesian neural networks have been included.

Advanced methodologies are taught to estimate and calibrate risk parameters: PD, LGD and EAD. The Lifetime PD estimate used in the IFRS 9 impairment models is exposed.

Methodologies and practical exercises of Stress testing in credit risk using advanced techniques of machine learning and deep learning are shown. And a practical exercise with financial statements to understand the impact of stress testing on capital and profits.

We have a global exercise to estimate the expected loss at 12 months and ECL lifetime using advanced credit risk methodologies, including PD, LGD, EAD, prepayment and interest rate curve models.

The course shows economic capital methodologies in credit card, mortgage, SME and Corporate portfolios. As well as capital allocation methodologies.

Quantum Machine Learning is the integration of quantum algorithms within Machine Learning programs. Machine learning algorithms are used to compute vast amounts of data, quantum machine learning uses qubits and quantum operations or specialized quantum systems to improve the speed of computation and data storage performed by algorithms in a program. For example, some mathematical and numerical techniques from quantum physics are applicable to classical deep learning. A quantum neural network has computational capabilities to decrease the number of steps, the qubits used, and the computation time.

The objective of the course is to show the use of quantum computing and tensor networks to improve the calculation of machine learning algorithms.

We show how quantum algorithms speed up the calculation of Monte Carlo simulation, the most powerful tool for developing credit risk models, representing an important advantage for calculating economic capital, lifetime PD and creating stress testing scenarios.

The objective of the course is to expose classical models against quantum models, explain the scope, benefits and opportunities.

WHO SHOULD ATTEND?

The Course is aimed at professionals from financial institutions interested in developing powerful credit scoring models and calibrating their output, as well as model managers in credit risk and data science departments.

For a better understanding of the topics it is necessary that the participant has knowledge of statistics and mathematics.

MACHINE LEARNING

Module 1: Machine Learning

- Definition of Machine Learning
- Machine Learning Methodology
    - Data Storage
    - Abstraction
    - Generalization
    - Assessment
- **Supervised Learning**
- **Unsupervised Learning**
- **Reinforcement Learning**
- **deep learning**
- Typology of Machine Learning algorithms
- Steps to Implement an Algorithm
    - information collection
    - Exploratory Analysis
    - Model Training
    - Model Evaluation
    - Model improvements
    - Machine Learning in consumer credit risk
- Machine Learning in credit scoring models
- Quantum Machine Learning

Module 2: EDA Exploratory Analysis

- Data typology
- transactional data
- Unstructured data embedded in text documents
- Social Media Data
- data sources
- Data review
- Target definition
- Time horizon of the target variable
- Sampling
    - Random Sampling
    - Stratified Sampling
    - Rebalanced Sampling
- Exploratory Analysis:
    - histograms
    - Q Q Plot
    - Moment analysis
    - boxplot
- Treatment of Missing values
    - Multivariate Imputation Model
- Advanced Outlier detection and treatment techniques
    - Univariate technique: winsorized and trimming
    - Multivariate Technique: Mahalanobis Distance
- **Exercise 1:** EDA Exploratory Analysis

Module 3: Univariate Analysis

- Data Standardization
- Variable categorization
    - Equal Interval Binning
    - Equal Frequency Binning

    - Chi-Square Test
- binary coding
- WOE Coding
    - WOE Definition
    - Univariate Analysis with Target variable
    - Variable Selection
    - Treatment of Continuous Variables
    - Treatment of Categorical Variables
    - gini
    - Information Value
    - Optimization of continuous variables
    - Optimization of categorical variables
- **Exercise 2:** Detection and treatment of Advanced Outliers
- **Exercise 3:** Stratified and Random Sampling in R
- **Exercise 4:** Multivariate imputation model
- **Exercise 5:** Univariate analysis in percentiles in R
- **Exercise 6:** Continuous variable optimal univariate analysis in Excel
- **Exercise 7:** Estimation of the KS, Gini and IV of each variable in Excel
- **Exercise 8:** Word Cloud analysis of variables in R

Unsupervised Learning

Module 4: Unsupervised models

- Hierarchical Clusters
- K Means
- standard algorithm
- Euclidean distance
- Principal Component Analysis (PCA)
- Advanced PCA Visualization
- Eigenvectors and Eigenvalues
- **Exercise 9:** Segmentation of the data with K-Means R

Supervised Learning

Module 5: Logistic Regression and LASSO Regression

- Econometric Models
    - Logit regression
    - probit regression
    - Piecewise Regression
    - survival models
- Machine Learning Models
    - Lasso Regression
    - Ridge Regression
- Model Risk in Logistic Regression
- **Exercise 10:** Credit Scoring Lasso Logistic Regression in R
- **Exercise 11:** Credit Scoring Ridge Regression in R

Module 6: Trees, KNN and Naive Bayes

- **Decision Trees**
    - modeling
    - Advantages and disadvantages
    - Recursion and Partitioning Processes

    - Recursive partitioning tree
    - Pruning Decision tree
    - Conditional inference tree
    - tree display
    - Measurement of decision tree prediction
    - CHAID model
    - Model C5.0
- **K-Nearest Neighbors KNN**
    - modeling
    - Advantages and disadvantages
    - Euclidean distance
    - Distance Manhattan
    - K value selection
- **Probabilistic Model: Naive Bayes**
    - naive bayes
    - Bayes' theorem
    - Laplace estimator
    - Classification with Naive Bayes
    - Advantages and disadvantages
- Exercise 12: Credit Scoring KNN and PCA

Module 7: Support Vector Machine SVM

- Support Vector Classification
- Support Vector Regression
- optimal hyperplane
- Support Vectors
- add costs
- Advantages and disadvantages
- SVM visualization
- Tuning SVM
- kernel trick
- **Exercise 14:** Credit Scoring Support Vector Machine in R

Module 8: Ensemble Learning

- Classification and regression ensemble models
- bagging
- bagging trees
- Random Forest
- Boosting
- adaboost
- Gradient Boosting Trees
- xgboost
- Advantages and disadvantages
- **Exercise 15:** Credit Scoring Boosting in R
- **Exercise 16:** Credit Scoring Bagging in R
- **Exercise 17:** Credit Scoring Random Forest, R and Python
- **Exercise 18:** Credit Scoring Gradient Boosting Trees

DEEP LEARNING

Module 9: Introduction to Deep Learning

- Definition and concept of deep learning
- Why now the use of deep learning?

- Neural network architectures
- feedforward network
- R deep learning
- Python deep learning
- Convolutional Neural Networks
- Use of deep learning in image classification
- cost function
- Gradient descending optimization
- Use of deep learning
    - How many hidden layers?
    - How many neurons, 100, 1000?
    - How many times and size of the batch size?
    - What is the best activation function?
- Deep Learning Software: Caffe, H20, Keras, Microsoft, Matlab, etc.
- Deployment software: Nvidia and Cuda
- Hardware, CPU, GPU and cloud environments
- Advantages and disadvantages of deep learning

Module 10: Deep Learning Feed Forward Neural Networks

- Single Layer Perceptron
- Multiple Layer Perceptron
- Neural network architectures
- activation function
    - sigmoidal
    - Rectified linear unit (Relu)
    - The U
    - Selu
    - hyperbolic hypertangent
    - Softmax
    - other
- Back propagation
    - Directional derivatives
    - gradients
    - Jacobians
    - Chain rule
    - Optimization and local and global minima
- **Exercise 19:** Credit Scoring using Deep Learning Feed Forward

Module 11: Deep Learning Convolutional Neural Networks CNN

- CNN for pictures
- Design and architectures
- convolution operation
- descending gradient
- filters
- strider
- padding
- Subsampling
- pooling
- fully connected
- Credit Scoring using CNN
- Recent CNN studies applied to credit risk and scoring
- **Exercise 20:** Credit scoring using deep learning CNN

Module 12: Deep Learning Recurrent Neural Networks RNN

- Natural Language Processing
- Natural Language Processing (NLP) text classification
- Long Term Short Term Memory (LSTM)
- hopfield
- Bidirectional associative memory
- descending gradient
- Global optimization methods
- RNN and LSTM for credit scoring
- One-way and two-way models
- Deep Bidirectional Transformers for Language Understanding
- **Exercise 21:** Credit Scoring using Deep Learning LSTM

Module 14: Generative Adversarial Networks (GANs)

- Generative Adversarial Networks (GANs)
- Fundamental components of the GANs
- GAN architectures
- Bidirectional GAN
- Training generative models
- Credit Scoring using GANs
- **Exercise 22:** Credit Scoring using GANs

Module 15: Calibration of Machine Learning and Deep Learning

- Hyperparameterization
- Grid search
- Random search
- Bayesian Optimization
- Train test split ratio
- Learning rate in optimization algorithms (e.g. gradient descent)
- Selection of optimization algorithm (e.g., gradient descent, stochastic gradient descent, or Adam optimizer)
- Activation function selection in a (nn) layer neural network (e.g. Sigmoid, ReLU, Tanh)
- Selection of loss, cost and custom function
- Number of hidden layers in an NN
- Number of activation units in each layer
- The drop-out rate in nn (dropout probability)
- Number of iterations (epochs) in training a nn
- Number of clusters in a clustering task
- Kernel or filter size in convolutional layers
- Pooling size
- Batch size
- **Exercise 23:** Optimization Credit Scoring Xboosting, Random forest and SVM
- **Exercise 24:** Optimized Credit Scoring Deep Learning

PROBABILISTIC MACHINE LEARNING

Module 16: Probabilistic Machine Learning

- Introduction to probabilistic machine learning
- Gaussian models
- Bayesian Statistics
- Bayesian logistic regression

- Kernel family
- Gaussian processes
    - Gaussian processes for regression
- Hidden Markov Model
- Markov chain Monte Carlo (MCMC)
    - Metropolis Hastings algorithm
- Machine Learning Probabilistic Model
- Bayesian Boosting
- Bayesian Neural Networks
- **Exercise 25:** Gaussian process for regression
- **Exercise 26:** Credit scoring model using Bayesian Neural Networks

MODEL VALIDATION

Module 17: Validation of traditional and Machine Learning models

- Model validation
- Validation of machine learning models
- Regulatory validation of machine learning models in Europe
- Out of Sample and Out of time validation
- Checking p-values in regressions
- R squared, MSE, MAD
- Waste diagnosis
- Goodness of Fit Test
- multicollinearity
- Binary case confusion matrix
- Multinomial case confusion matrix
- Main discriminant power tests
- confidence intervals
- Jackknifing with discriminant power test
- Bootstrapping with discriminant power test
- Kappa statistic
- K-Fold Cross Validation
- **Exercise 27:** Credit scoring model using logistic regression
- **Exercise 28:** Gini Estimation, Information Value, Brier Score, Lift Curve, CAP, ROC, Divergence in Excel
- **Exercise 29:** Jackkinifng in SAS
- **Exercise 30:** Bootstrapping in R
- **Exercise 31:** K-Fold Cross Validation in R

Module 18: Stability tests

- Model stability index
- Factor stability index
- Xi-square test
- K-S test
- **Exercise 32:** Stability tests of models and factors

AUTOMACHINE LEARNING and XAI

Module 19: Automation of Credit Scoring and PD Modeling

- What is modeling automation?
- that is automated

- Automation of machine learning processes
- Optimizers and Evaluators
- Modeling Automation Workflow Components
    - Summary
    - Indicted
    - Feature engineering
    - Model generation
    - Assessment
- Hyperparameter optimization
- Reconstruction or recalibration of credit scoring
- Credit Scoring Modeling
    - Main milestones
    - Evaluation and optimization
    - Possible Issues
- PD calibration modeling
    - Evaluation and optimization
    - backtesting
    - Discriminating Power
    - Stability Tests
- Global evaluation of modeling automation
- Implementation of modeling automation in banking
- Technological requirements
- available tools
- Benefits and possible ROI estimation
- Main Issues
- Model Risk
- Genetic algorithms
- **Exercise 33:** Automation of the modeling, optimization and validation of credit scoring hyperparametry
- **Exercise 34:** Automation of PD modeling and validation

Explainable Artificial Intelligence

Module 20: Explainable Artificial Intelligence XAI

- interpretability problem
- model risk
- Regulation of the General Data Protection Regulation GDPR
- EBA discussion paper on machine learning for IRB models
    - 1. The challenge of interpreting the results,
    - 2. The challenge of ensuring that management functions adequately understand the models, and
    - 3. The challenge of justifying the results to supervisors
- Black Box Models vs. Transparent and Interpretable Algorithms
- interpretability tools
- Shap, Shapley Additive explanations
    - Global Explanations
    - Dependency Plot
    - Decision Plot
    - Local Explanations Waterfall Plot
- Lime, agnostic explanations of the local interpretable model
- Explainer Dashboard
- Other advanced tools
- **Exercise 35:** XAI interpretability of credit scoring

Module 21: Quantum computing and algorithms

Objective: Quantum computing applies quantum mechanical phenomena. On a small scale, physical matter exhibits properties of both particles and waves, and quantum computing takes advantage of this behavior using specialized hardware. The basic unit of information in quantum computing is the qubit, similar to the bit in traditional digital electronics. Unlike a classical bit, a qubit can exist in a superposition of its two "basic" states, meaning that it is in both states simultaneously.

- Future of quantum computing in insurance
- Is it necessary to know quantum mechanics?
- QIS Hardware and Apps
- quantum operations
- Qubit representation
- Measurement
- Overlap
- matrix multiplication
- Qubit operations
- Multiple Quantum Circuits
- Entanglement
- Deutsch Algorithm
- Quantum Fourier transform and search algorithms
- Hybrid quantum-classical algorithms
- Quantum annealing, simulation and optimization of algorithms
- Quantum machine learning algorithms
- **Exercise 36:** Quantum operations multi-exercises

Module 22: Introduction to quantum mechanics

- Quantum mechanical theory
- wave function
- Schrodinger's equation
- statistical interpretation
- Probability
- Standardization
- Impulse
- The uncertainty principle
- Mathematical Tools of Quantum Mechanics
- Hilbert space and wave functions
- The linear vector space
- Hilbert's space
- Dimension and bases of a Vector Space
- Integrable square functions: wave functions
- Dirac notation
- operators
- General definitions
- hermitian adjunct
- projection operators
- commutator algebra
- Uncertainty relationship between two operators
- Operator Functions
- Inverse and Unitary Operators
- Eigenvalues and Eigenvectors of an operator
- Infinitesimal and finite unit transformations
- Matrices and Wave Mechanics
- matrix mechanics

- Wave Mechanics
- **Exercise 37:** Quantum mechanics multi-exercises

Module 23: Introduction to quantum error correction

- Error correction
- From reversible classical error correction to simple quantum error correction
- The quantum error correction criterion
- The distance of a quantum error correction code
- Content of the quantum error correction criterion and the quantum Hamming bound criterion
- Digitization of quantum noise
- Classic linear codes
- Calderbank, Shor and Steane codes
- Stabilizer Quantum Error Correction Codes
- **Exercise 38:** Noise Model, Repetition Code and quantum circuit

Module 24: Quantum Computing II

- Quantum programming
- Solution Providers
    - IBM Quantum Qiskit
    - Amazon Braket
    - PennyLane
    - cirq
    - Quantum Development Kit (QDK)
    - Quantum clouds
    - Microsoft Quantum
    - Qiskit
- Main Algorithms
    - Grover's algorithm
    - Deutsch–Jozsa algorithm
    - Fourier transform algorithm
    - Shor's algorithm
- Quantum annealers
- D-Wave implementation
- Qiskit Implementation
- **Exercise 39:** Quantum Circuits, Grover Algorithm Simulation, Fourier Transform and Shor

Module 25: Quantum Machine Learning

- Quantum Machine Learning
- hybrid models
- Quantum Principal Component Analysis
- Q means vs. K means
- Variational Quantum Classifiers
- Variational quantum classifiers
- Quantum Neural Network
    - Quantum Convolutional Neural Network
    - Quantum Long Short Memory LSTM
- Quantum Support Vector Machine (QSVC)
- **Exercise 40:** Quantum Support Vector Machine

Module 26: Tensor Networks for Machine Learning

- What are tensor networks?
- Quantum Entanglement

- Tensor networks in machine learning
- Tensor networks in unsupervised models
- Tensor networks in SVM
- Tensor networks in NN
- NN tensioning
- Application of tensor networks in credit scoring models
- **Exercise 41:** Neural Network using tensor networks

CREDIT SCORING

Module 27: Quantum Credit Scoring

- Scoring assignment
- Scorecard Classification
  - Scorecard WOE
  - Binary Scorecard
  - Continuous Scorecard
- Scorecard Rescaling
  - Factor and Offset Analysis
  - Scorecard WOE
  - Binary Scorecard
- What is quantum machine learning?
- Qubit and Quantum States
- Quantum Automatic Machine Algorithms
- quantum circuits
- quantum k means
- Support Vector Machine
- Support Vector Quantum Machine
- Variational quantum classifier
- Training quantum machine learning models
- Quantum Neural Networks
- Quantum GAN
- Quantum Boltzmann machines
- Quantum machine learning in Credit Risk
- Quantum machine learning in credit scoring
- quantum software
- **Exercise 42:** Quantum K-means
- **Exercise 43:** Quantum Support Vector Machine to develop credit scoring model
- **Exercise 44:** Quantum feed forward Neural Networks to develop a credit scoring model
- **Exercise 45:** Quantum Convoluted Neural Networks to develop a credit scoring model

PD Quantum and Machine Learning Models

Module 28: Quantum and Machine Learning Models of PD

- PD estimation
- Treatment of Panel data
- PD Machine Learning Models
  - PD COX regression of survival
    - Cox XGBoost,
    - Survival Tree
    - Random Survival Forest
  - PD Bayesian Logistic Regression
  - PS Regression Lasso

  - PS SVM
  - PS Neural Networks
  - PS Quantum Neural Networks
- PD Calibration
- Calibration of econometric models
- Anchor Point Estimate
- PD calibration by vintages or vintages
- vintage analysis
  - PS Marginal
  - PS Forward
  - Cumulative PD

Exercise 46: PD Calibration with COX XGBOOST Regression
Exercise 47: Calibration of the PD with Quantum SVM
Exercise 48: Calibration of PD with Neural Networks in R
Exercise 49: PD Calibration with Bayesian Logistic Regression in Python
Exercise 50: Calibration of the LASSO regression PD
Exercise 51: PD calibration with quantum neural networks in Python

Module 29: PD Calibration

- Concept of adjustment to central tendency
- Bayesian approach
- PD calibration in developed countries
- PD calibration in emerging countries
- Scaled PD Calibration
- Scaled Likelihood ratio calibration
- Smoothing of PD curves
- quasi moment matching
- approximation methods
  - Scaled beta distribution
  - Asymmetric Laplace distribution
- rubber function
- Platt scaling
- Broken curve model
- Isotonic regression
- Gaussian Process Regression
- **Exercise 52:** PD calibration using Platt scaling and isotonic regression for traditional and quantum machine learning models
- **Exercise 53:** PD calibration using Gaussian Process Regression

Module 30: Bayesian PD and Gaussian Process

- Bayesian and deterministic approach
- expert judgment
- prior distributions
- Bayes' theorem
- posterior distributions
- Bayesian PD Estimation
- Markov Chain–Monte Carlo MCMC approach
- credibility intervals
- Bayesian PD in practice
- Calibration with Bayesian approach
- Process Gaussian regression
- **Exercise 39:** Bayesian PD of logistic model in Python
- **Exercise 54:** PD using MCMC in R
- **Exercise 55:** PD using Process Gaussian Regression

Module 31: IFRS 9 PD Forecasting

- IFRS 9 requirements
    - Probability Weighted Outcome
    - Forward Looking
- Lifetime PD modeling
- PD Forecasting Modeling
- PD Point in Time Forecasting
- PS TTC Forecasting
- Markov models
- PIT PD Forecasting Models
    - ARIMA
    - VAR
    - VARMAX
    - ASRF
    - Traditional LSTM
    - Bayesian LSTM
    - Quantum LSTM
- **Exercise 56:** Forecasting PD using VARMAX in R
- **Exercise 57:** PD forecasting using quantum LSTM

Module 32: Lifetime PD

- PD Lifetime consumer portfolio
- PD Lifetime mortgage portfolio
- PD Lifetime Wallet Credit Card
- PD Lifetime portfolio SMEs
- vintage model
    - Exogenous Maturity Vintage EMV Model
    - decomposition analysis
    - COVID-19 Pandemic Application
    - Advantages and disadvantages
- Basel ASRF model
    - Matrix ASRF model
    - Leveraging IRB in IFRS 9
    - Advantages and disadvantages
- Regression Models
    - Logistic Multinomial Regression
    - Ordinal Probit Regression
- Survival Models
    - Kaplan–Meier
    - Cox Regression
    - Advantages and disadvantages
- Markov models
    - Multi-State Markov Model
    - Advantages and disadvantages
- Machine Learning Model
    - Support Vector Machine
- Deep Learning Models
    - Neural network architecture
- PD Lifetime Extrapolation Models
- Lifetime PD Calibration
- **Exercise 58:** PD Lifetime using multinomial regression in R
- **Exercise 59:** PD Lifetime using Multi State Markov model
- **Exercise 60:** PD Lifetime using matrix ASRF model
- **Exercise 61:** PD Lifetime using Quantum SVM
- **Exercise 62:** PD Lifetime using traditional SVM in Python

- **Exercise 63:** PD Lifetime using traditional Deep Learning
- **Exercise 64:** PD Lifetime using Quantum Deep Learning

Module 33: LGD for IFRS 9

- Comparison of IRB LGD vs. IFRS 9
- Impact on COVID-19
- IFRS 9 requirements
    - Probability Weighted
    - Forward Looking
- IRB LGD adjustments
    - Selection of Interest Rates
    - Allocation of Costs
    - floors
    - Treatment of collateral over time
    - Duration of COVID-19
- LGD PIT modeling
- Collateral Modeling
- LGD IFRS 9 for portfolio companies
- LGD IFRS 9 for mortgage portfolio
- LGD IFRS 9 for corporate portfolios
- IFRS 9 LGD using LASSO Regression
- Machine Learning Models
    - Support Vector Machine
    - Random Forest
    - xgboost
    - Neural Networks
- **Exercise 65:** Estimation and adjustments for LGD IFRS 9 using Random Forest regression
- **Exercise 66:** Beta Regression and Neural Networks
- **Exercise 67:** Estimating IFRS 9 LGD using Xgboost regression in Python
- **Exercise 68:** LGD estimation using traditional SVM
- **Exercise 69:** LGD estimation using quantum SVM
- **Exercise 70:** LGD estimation using traditional neural networks
- **Exercise 71:** LGD estimation using Bayesian neural networks

EAD IFRS 9

Module 34: Advanced EAD and CCF modeling for IRB

- Impact of COVID-19 on credit lines
- Guidelines for estimating CCF
- Guidelines for Estimating CCF Downturn
- Temporal horizon
- Transformations to model the CCF
- Approaches to Estimating CCF
    - Fixed Horizon approach
    - Cohort Approach
    - Variable focus time horizon
- Econometric Models
    - Beta regression
    - Inflated beta regression
    - Fractional Response Regression
    - Mixed Effect Model
- Machine Learning Models
    - neural networks
    - SVM

- Intensity model to measure the withdrawal of credit lines
- **Exercise 72:** CCF neural network regression model
- **Exercise 73:** CCF Support Vector Regression Model in Python
- **Exercise 74:** Neural Networks and CCF beta regression in R
- **Exercise 75:** CCF Quantum SVM and Classic Regression SVM

Prepaid

Module 35: Contractual Options

- Prepaid and other options
- IFRS 9 requirements
- Probability Weighted
- Forward Looking
- IFRS 9 prepayment modeling
    - Cox Regression
    - Logistic regression
- Survival rate estimate
- Joint Probability Model with PD Lifetime
- **Exercise 76:** Random forest regression prepayment model in R and Excel

Module 36: EAD Lifetime for Lines of Credit

- Impact of the pandemic on the use of credit lines
- Lifetime measurement in credit cards
- Lifetime EAD
- IFRS 9 requirements
- Probability Weighted
- Forward Looking
- Adjustments in the EAD
- Interest Accrual
- CCF PIT Estimate
- CCF Lifetime Estimate
- EAD lifetime modeling
- Model of the use of credit lines with macroeconomic variables
- Credit card abandonment adjustment
- EAD Lifetime model for pool of lines of credit
    - vintage model
    - Chain Ladder Approach
- **Exercise 77:** Neural network model for line of credit
- **Exercise 78:** EAD Lifetime model for line of credit

BACKTESTING VALIDATION

Module 37: PD Backtesting

- PD validation
- Backtesting PS
- PD Calibration Validation
- Hosmer Lameshow test
- normal test
- Binomial Test
- Spiegelhalter test
- Redelmeier Test
- Traffic Light Approach

- Traffic Light Analysis and PD Dashboard
- PS Stability Test
- Forecasting PD vs Real PD in time
- Validation with Monte Carlo simulation
- **Exercise 79:** Backtesting PD in Excel

Module 38: LGD Backtesting

- LGD Backtesting
- Accuracy ratio
- absolute accuracy indicator
- Confidence Intervals
- transition analysis
- RR Analysis using Triangles
- Advanced LGD Backtesting with a vintage approach
- Backtesting for econometric models:
- test calibration
- t-test
- Wilcoxon signed rank test
- Accuracy Test
- F Test
- Ansari–Bradley Test
- **Exercise 80:** Comparison of the performance of the models using Calibration and precision tests.

Module 39: EAD Backtesting

- EAD Performance
- r squared
- Pearson coefficient
- Spearman correlation
- Validation using ROC, KS and Gini
- **Exercise 81:** Comparison of the performance of EAD models

AI STRESS TESTING

Module 40: Modernization of macroeconomic dynamics using Deep Learning

- Macroeconomic models
- Neoclassical growth model
- Partial differential equations
- DSGE Stochastic Dynamic General Equilibrium Models
- Deep learning architectures
- Reinforcement Learning
- Advanced Scenario Analysis
- **Exercise 82:** Bellman equation macroeconomic model using neural networks

Module 41: Deep Learning models for macroeconomic projections

- Trading strategies with forecasting models
- Multivariate Models
    - VAR Autoregressive Vector Models
    - ARCH models
    - GARCH models
    - GARCH Models Multivariate Copulas
    - VEC Error Correction Vector Model
    - Johansen's method

- Machine Learning Models
    - Supported Vector Machine
    - neural network
        - Forecasting market time series yields
        - NN and SVM algorithms for performance forecasting
        - Forecasting volatility NN vs. Garch
    - Development and validation base
- Deep learning
    - Recurrent Neural Networks RNN
    - Elman's Neural Network
    - Jordan Neural Network
    - Basic structure of RNN
    - Long short term memory LSTM
    - temporary windows
    - Development and validation sample
    - Regression
    - Sequence modeling
- Quantum Deep Learning
- Time series analysis with Facebook Prophet
- Prediction of the spread of Covid-19
- **Exercise 83:** Charge-off model with VAR and VEC
- **Exercise 84:** Forecasting financial series and Bayesian LSTM indices in Python
- **Exercise 85:** Pandemic Forecasting using Multivariate RNN LSTM in Python
- **Exercise 86:** Forecasting using quantum neural networks

Module 42: Stress Testing PD and LGD

- Temporal horizon
- Multi-period approach
- Data required
- Impact on P&L, RWA and Capital
- Macroeconomic Stress Scenarios in consumption
    - Expert
    - Statistical
    - regulatory
- PD Stress Testing:
    - Credit Portfolio View
    - Multiyear Approach
    - Reverse Stress Testing
    - Rescaling
    - Cox Regression
- Stress Testing of the Transition Matrix
    - Approach Credit Portfolio View
    - credit cycle index
    - Multifactor Extension
- LGD Stress Testing:
    - LGD Downturn: Mixed Distribution Approach
    - PD/LGD Multiyear Approach modeling
    - LGD stress test for mortgage portfolios
- Stress Testing of:
    - Net Charge Off
    - Rating/Scoring transition matrices
    - Recovery Rate and LGD
- **Exercise 52:** Stress Testing PD in Excel and SAS multifactorial model Credit Portfolio Views
- **Exercise 87:** Stress Testing PD using Bayesian LSTM
- **Exercise 88:** PD stress test using Variational Quantum Regression
- **Exercise 89:** LGD Stress Test using MARS Model

- **Exercise 90:** LGD Stress Test using LASSO regression

Module 43: Stress Testing in corporate portfolios

- Temporal horizon
- Data required
- Main Macroeconomic variables
- Impact on P&L, RWA and Capital
- ASRF model
- Creditmetrics model
- Using Transition Matrices
- Use of the credit cycle index
- Default forecasting
- Stress Test Methodology for corporate portfolios
- Impact on RWA and Capital
- **Exercise 91:** Stress Testing PD and corporate portfolio transition matrices using transition matrix and ASRF model in SAS, R and Excel

Module 44: Quantum Stress Testing

- Quantum economics
- Classic Monte Carlo simulation
- Quantum Monte Carlo
- Coding Monte Carlo problem
- Breadth Estimation
- Acceleration applying the amplitude estimation algorithm
- DGSE model using neural networks
- Quantum Monte Carlo Simulation vs Normal Monte Carlo Simulation
- **Exercise 95:** DGSE model using deep learning
- **Exercise 92:** Quantum Monte Carlo Simulation vs. Classical Monte Carlo Simulation

CREDIT RISK OF PORTFOLIO

Module 45: Economic Capital Models

- Regulatory Capital
- Economic Capital Methodologies
- Correlation of Assets and Default
- Unexpected Tax Loss
- ASRF Economic Capital Models
- Business Models
    - kmv
    - creditmetrics
    - Credit Portfolio View
    - Credit risk +
- Economic capital management
- Allocating Economic Capital
- **Exercise 93:** Portfolio Approach: Estimation of EL, UL, ULC, Correlation and Economic Capital in Excel
- **Exercise 94:** Creditrisk + in SAS
- **Exercise 95:** Creditmetrics in Excel and R
- **Exercise 96:** Single-factor model in Excel

Module 46: Quantum Economic Capital

- Distribution of credit risk losses
- Quantum uncertainty model
- Circuit Definition
- Quadratic acceleration over the classical Monte Carlo simulation
- expected loss
- Cumulative distribution function
- VaR
- Expected Shortfall
- **Exercise 97:** Estimation EL, VAR, ES of quantum credit risk

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