Credit Risk Fundamentals

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Introduction

Brainstorming

- What do you know about credit risk?

- What do you think are the following?

PD

EAD

ECL

LGD

DEFAULT

RWA

Section 2

Credit Risk Overview

What is credit risk?

- Risk of a loss due to the failure of a counterparty to honour contractual obligations
- It comes in different flavours:
  - Default risk
  - Downgrade risk
- It is omnipresent in the portfolio of a typical financial institution
  - Related to core activities of most banks
  - Highly relevant to insurance companies
- Its management involves a wide range of tasks
  - Determination of capital that should be held to absorb possible losses due to credit risk
  - Managing credit risk on institution's balance sheet
  - Diversification of the portfolio of credit-risky instruments
  - Control of the counterparty credit risk (very important in the aftermath of the 2007-9 crisis)

Credit-risky instruments (1) – loans and bonds

- Loans (*retail, corporate, interbank, sovereign*) and bonds (*corporate bonds, treasuries, sovereign bonds, convertible bonds*) are the simplest credit-risky instruments
- Sum of money (*principal*) advanced to borrower for a particular term in exchange for a series of defined *interest payments*.
- Loans:
  - Private agreements between the borrower and lender
  - Secured / unsecured
- Bonds:
  - Publicly traded securities issued by companies and governments
- *Exposure* is the value of the outstanding principal and interest payments

Credit-risky instruments (2) - derivatives

OTC derivatives:

- Over the counter (OTC) derivatives make a significant portion of all derivative transactions
- OTC is a contract between two parties, there is no central clearing counterparty (organized exchange) hence such derivatives are subject to *counterparty credit risk*.
- The size of counterparty credit exposure is not known a priori (e.g. interest-rate swap between A and B)
- Risk-mitigation techniques such as *netting* and *collateralization* are used.

Credit Default Swaps (CDS):

- Securities used for hedging and trading of credit risk.
- Promised pay-off in case of a default event.
- Proteciton againg losses or speculative motives – often more liquid than bond markets.

PD, LGD, and EAD

Key inputs to the Basel formula:

- **EAD** = exposure at default

  Outstanding amount the borrower (obligor) has yet to repay to the lender at the time of default.

- **PD** = probability of default

  Probability that the borrower will default over a given time horizon.

- **LGD** = loss given default

  Percentage loss the lender suffers given the default of a borrower.

- **ECL** = expected credit loss

$$\text{ECL} = \text{PD} \cdot \text{LGD} \cdot \text{EAD}$$

Any possible problems with this formula?

Section 3

Regulatory Capital and RWA

Regulatory framework

Why a need for global capital requirements / regulations?

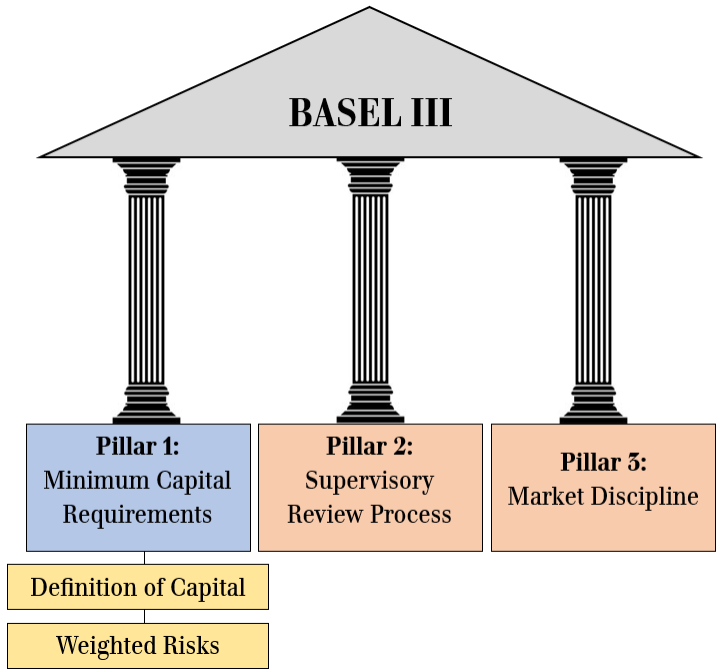
- 1980s: fast increase of derivative trading + banks competing globally
- Regulations are introduced:
  - To strengthen stability of international banking system.
  - To provide a level-playing field by use of uniform regulations.

Milestones:

- 1988: Basel I – introduction of minimum ratio of capital / RWA of 8%
- 2004: Basel II – establisment of the three-pillar system of regulation
- 2011: Basel III
  - increase of the required capital quality and amount,
  - ratios to ensure sufficient funding liquidity, etc

The Three Pillars of Basel III

- **Pillar 1: Minimal Capital Requirements**
  - Banks need to have capital for covering losses.
  - Credit risk is one of the most important risks in banks' balance sheets
- **Pillar 2: Supervisory Review Process**
  - Regular self-assessment of risk profiles
  - Adequate risk management practices
- **Pillar 3: Market Discipline**
  - Comprehensive set of disclosure requirements – banks need to disclose their risk management practices, capital adequacy, and other key financial information to the public

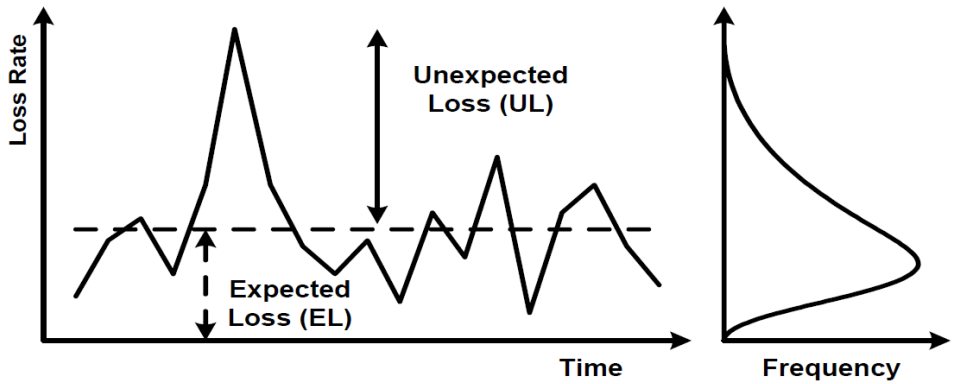


Expected and unexpected losses (1)

- Credit business:
  - losses of interest/principal occur all the time
  - Losses vary year-to-year

    Expected Losses (EL) = average level of credit losses within a one-year horizon

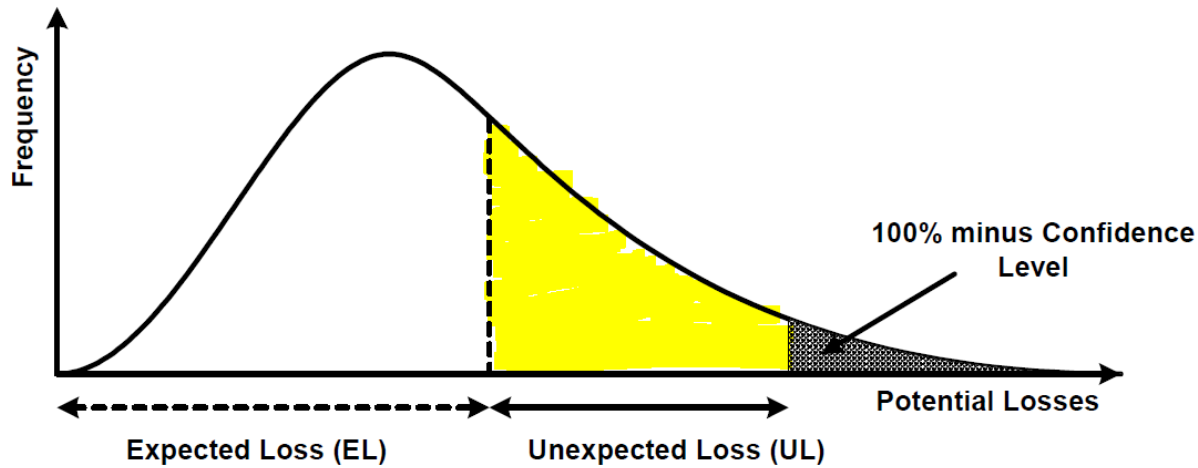
    Unexpected Losses (UL) = losses above expected level (do not occur every year, can be severe)



- Expected losses – forecasted by banks and covered through pricing of credit exposures and provisioning
- Unexpected losses – need to be covered by banks' capital => capital requirements

Expected and unexpected losses (2)

- Likelihood of losses as a function of magnitude
  - Small losses (around and slightly below EL) more frequent than large losses
  - Unexpected losses should be covered by bank's profits and capital (yellow area)
  - Likelihood that losses are kept within EL and UL is equal to 100% minus (assumed) confidence level
  - Likelihood that losses exceed EL and UL is equal to the (assumed) confidence level (grey area)



Capital requirements - example

- Sample balance sheet of a bank (source: [1], sec. 2.1)

  Bank needs to keep enough capital to cover unexpected losses – regulatory capital framework specifies the amount of capital necessary to continue operations

Table 2.1. The stylized balance sheet of a typical bank.

Bank ABC (31 December 2015)			
Assets		Liabilities	
Cash	£10M	Customer deposits	£80M
(and central bank balance)			
Securities	£50M	Bonds issued	
– bonds		– senior bond issues	£25M
– stocks		– subordinated bond issues	£15M
– derivatives		Short-term borrowing	£30M
Loans and mortgages	£100M	Reserves (for losses on loans)	£20M
– corporates			
– retail and smaller clients		*Debt (sum of above)*	£170M
– government			
Other assets	£20M		
– property			
– investments in companies		*Equity*	£30M
Short-term lending	£20M		
Total	£200M	Total	£200M

Definitions of capital and capital ratios

- Basel Committee sets international standards to monitor banks' capital adequacy
- Capital types:
  - Tier 1 capital; further split
    - CET1 = Common Equity Tier 1: core capital (common shares, retained earnings)
    - AT1 = Additional Tier 1: financial instruments that can be converted into equity in crisis event
  - Tier 2 capital:
    Financial instruments representing supplementary capital.
- Three main capital ratios and minimum capital requirements

CET 1 Ratio	Tier 1 Ratio	Total Capital Ratio
CET 1	**CET 1 + AT 1**	**Tier 1 + Tier 2**
requirement = 4.5%	requirement = 6.0%	requirement = 8.0%

- Supervisors can impose additional requirements on top of the minimum capital ratios

Section 4

More on Credit Risk

Credit risk – why bother?

- The size and number of default events in a given year is unknown
- However, we know that the size of such losses can increase in stress periods
- Two main types of risk that affect portfolio:

  – Systematic risk = risk related to broad macroeconomic events, such as:
    - COVID-19 crisis
    - Global Financial Crisis (2007-2009)
    - Oil Crisis (1973)

  – Idiosyncratic risk = risk related to specific features of the borrower; it includes
    - Concentration risk
    - Liquidity risk

Credit risk - examples

- Default risk: the risk that the borrower is unable/unwilling to make payments
- Result: loss of wither principal, interest payments, or both

Examples of obligors:

- Company has borrowed money from a bank.
- Company has issued bonds.
- Household borrowed money from a bank to buy a house (a mortgage).
- Bank has entered a billateral financial contract (e.g. an interest-rate swap) with a large corporation.

Examples of defaults:

- Company goes bankrupt and is unable to repay the loan.
- Company fails to pay a coupon for some of its issued bonds in the agreed time.
- Household fails to pay amortisation or interests on their mortgage.
- A large goes bankrupt and is unable to deliver on agreed interest-rate payments.

Credit risk – how to measure?

- Standardised approach
  - Exposures classified into various vategories based on the counterparty or the underlying
  - Different Risk Weights (RWs) applied, depending on the category counterparties belong and their rating
  - Ratings provided by external credit-rating agencies

- Internal Ratings-Based (IRB) approach
  - Introduced in Basel II framework for capiutal adequacy
  - Enables banks to use own internal models to estimate PD, EAD, and LGD for individual counterparties.
  - Enables banks to more accurately assess credit risk and allocate capital accordingly.
  - This approach is subject to regulatory oversight (certain minimum requirements have for data quality, model development, validation)

Credit risk – Standardised approach

- Risk weights according to category and rating

Rating	Sovereign	Banks	Corporate	Retail	Real Estate
[AAA, AA-]	0%	20%	20%	75%	[35%, 100%]
[A+, A-]	20%	50%	50%		
[BBB+, BBB-]	50%	50%	100%		
[BB+, BB-]	100%	100%	100%		
[B+, B-]	100%	100%	150%		
[CCC+, CCC-]	150%	150%	150%		
No Rating	100%	50%	100%		

Credit risk – IRB approach

- Basel I, 1988 – important step towards minimum capital standards but…

  The appraoch was coars (three crude categories – governments / regulated banks / others).

- Basel II, 2004 – banks are allowed to use internal-ratings-based (IRB) approach

  Finer, more risk-sensitive appraoach to assessing risk of banks' credit portfolios.

  In particular, (source [3]):

> implementation processes. The June 2004 paper takes account of new developments in the measurement and management of banking risks for those banks that move onto the "internal ratings-based" (IRB) approach. In this approach, institutions will be allowed to use their own internal measures for key drivers of credit risk as primary inputs to the capital calculation, subject to meeting certain conditions and to explicit supervisory approval. All institutions

Potential approach	Default Probability (PD)	Loss Given Default (LGD)	Exposure at Default (EAD)
Foundation IRB	Estimated by the institution	Regulatory values	Regulatory values
Advanced IRB	Estimated by the institution	Estimated by the institution	Estimated by the institution

Credit risk – Default probabilities

- Probability of default:
  - The likelihood of a borrower or counterparty defaulting on its financial obligations over a specified period of time (e.g. one year)
  - Key input used in credit-risk models to estimate expected losses of a portfolio.
  - Used to calculate regulatory capital requirements under the Basel Accords.

- How to calculate it? ← Needed for the project.

Section 5

Estimation of PD

Models for PD estimation

Types of models for PD estimation:

- Credit-scoring models:
  - Statistical analysis based on a set of economic and financial indicators (weighted)
  - Credit score is a numerical value representing the borrower's likelihood of default (PD)

- Capital-markets models:
  - Analysis of market data to compute borrower's PD
  - Various types of models:
    - Structural models: Merton model, KMV model
    - Reduced-form models: Jarrow-Turnbull model
    - Credit Default Swap (CDS) models

Credit Scoring – Linear Discriminant Analysis (1)

- Linear discriminant analysis: a *classification technique* that uses some *discriminant function* to distinguish between categories (reliable or insolvent companies)
- Goal: find the linear combination of predictor variables ($x_{i,j}$) that best separates the data into different categories; e.g. z-score of the i-th company

$$z_i = \sum_{j=1}^{n} \gamma_j \, x_{i,j}$$

j $\in \{1, \dots, n\}$: independent predictor variables;

γ_j : weights to maximize the distance between z_A (reliable) and z_A (insolvent) companies

- Assessing model performance: Wilk's lambda

$$\Lambda = \frac{\sum_{i \in A} (z_i - z_A)^2 + \sum_{i \in B} (z_i - z_B)^2}{\sum_{i=1}^{n} (z_i - \overline{z})^2}$$

What is the best lambda?

Credit Scoring – Linear Discriminant Analysis (2)

- Altman Z-score:
  - well-known discriminant score for listed companies (developed in the 60s)
  - Uses a linear combination of five financial ratios with specific weights (importance):

$$Z = 1.2\,X_1 + 1.4\,X_2 + 3.3\,X_3 + 0.6\,X_4 + 1.0\,X_5$$

    - X_1 = working capital / total assets
    - X_2 = retained earnings / total assets
    - X_3 = earnings before interest and taxes / total assets
    - X_4 = market value of equity / total liabilities
    - X_5 = sales / total assets

- The higher the score, the safer the company:
  - Original work: z_A = +4.48 (realiable) and z_B = -0.25 insolvent
  - Cutoff between realiable/insolvent: z ~ 1.8
- PD can be derived from Z-score via a suitable *mapping function*.

Credit Scoring – Regression Models (1)

- Regression model: statistical tool to analyze a relationshp between dependent variable and one (or more) independent variables.
- Goal: establish a relationship (β_i) between the dependent variable – outcome (y_i) and independent variables – predictors ($x_{i,j}$)

$$y_i = \alpha + \sum_{j=1}^{n} \beta_j \, x_{i,j} + \varepsilon_i$$

- Procedure:
  1. Sample selection
  2. Independent variables selection
  3. Coefficient estimate, e.g. ordinary least squares – OLS – fitting regression coefficients such that the error term (ε_i) is minimised
- Finally: PD computation – by using the estimated regression coefficients

Credit Scoring – Regression Models (2)

PD estimation:

- Y = binary dependent variable
  - Y=0: reliable company (no default)
  - Y=1: insolvent company (default)
- Write probability of default as:

$$P(Y = 1|X) = F(\beta_0 + \beta_1 X_1 + \beta_2 X_2 + \cdots + \beta_n X_n)$$

  Where F is a *link function* and $X_1, \ldots, X_n$ are the selected independent variables.
- Using a data sample (list of companies with known variables X_j and default flag) regression parameters β_j can be estimated.

Credit Scoring – Regression Models (3)

Binary logistic regression major assumptions:

- The dependent variable should be dichotomous.

  e.g. presence vs. absence, default vs. alive

- There should be no outliers in the data.

  This can be assessed by converting the continous predictors to standardized scores and removing extremely high/extremely low values.

- There should be no high correlations among the predictor variables.

  This can be assessed by analysis of a correlation matrix among the predictors. It is suggested that as long as correlation coefficients among variables are less than 0.9 the assumption is met.

Note:

- Based on a choice of link function, different regression models can be obtained.

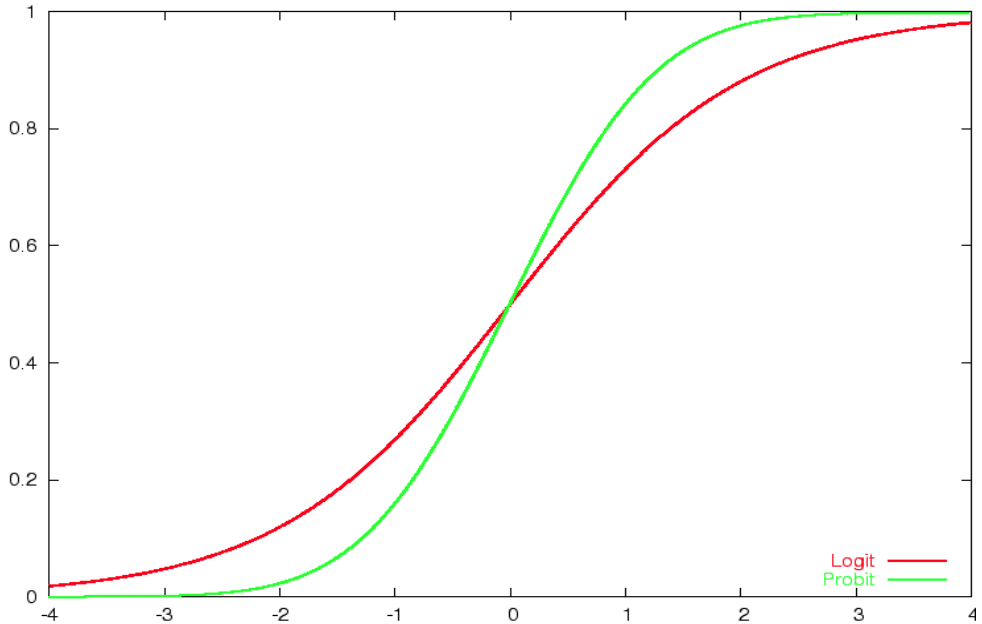
  For PD estimation the most common choices include probit or logit models.

Credit Scoring – Regression Models (4)

- Probit model: $F(x) = \Phi(x)$, with Φ being the CDF of standard normal distribution.
- Logit model: $F(x) = 1/(1 + e^x)$

Basic properties:

- Logit has heavier tails
- Probit is more centered



Which one is better?

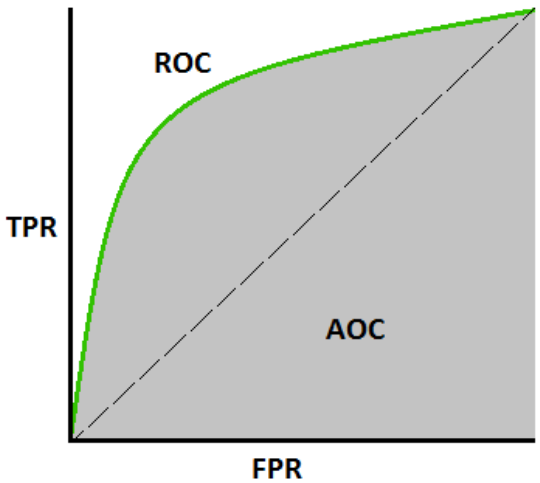
Both will yield similar (but not identical) results. Details can differ for mode advanced setups.

ROC – Receiver Operating Characteristic (1)

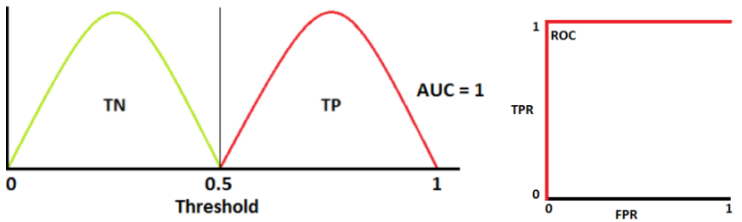
- The ROC curve says how much the model is capable of distinguishing between classes.
- Possible results:
  - TP = true positive (1 classified as 1); FP = false positive (0 classified as 1)
  - TN = true negative (0 classified as 0); FN = false negative (1 classified as 0)

  Note: 1 = default; 0 = no default
- Define: true positive rate and false positive rate

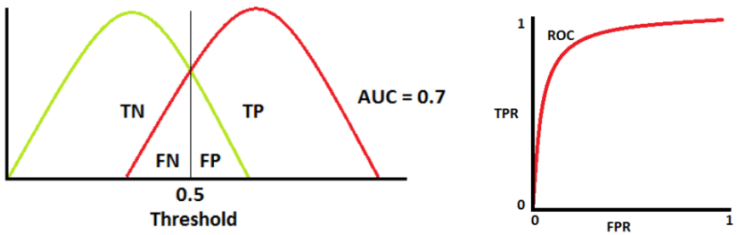
  TPR = TP / (TP + FN)
  FPR = FP / (FP + TN)
- Plot ROC curve: TPR vs. FPR
- The higher the AUC (area under curve), the better predition power of a model.



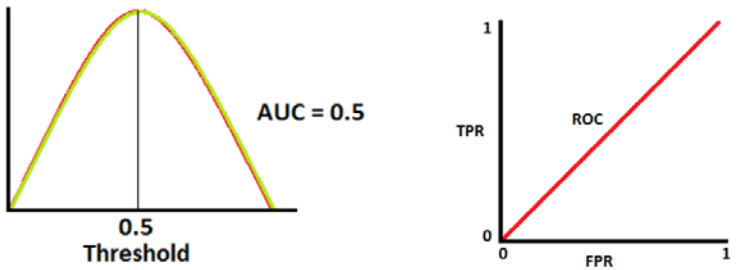
ROC – Receiver Operating Characteristic (2)



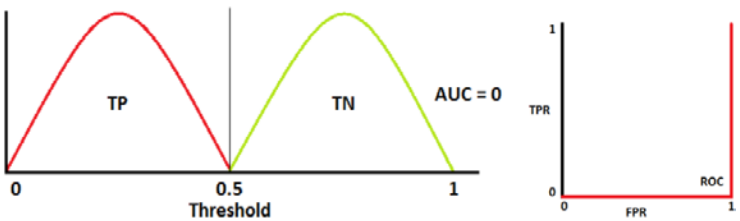
An ideal situation. When two curves do not overlap at all means model has an ideal measure of separability i.e., it perfectly distinguishes between 0s and 1s.



When two distributions overlap, we introduce type 1 and type 2 error. Depending upon the threshold, we can minimize or maximize them. AUC = 0.7 means there is a 70% chance that model will be able to distinguish between 1s and 0s.



This is the worst situation. When AUC is approximately 0.5, model has no discriminatory power to distinguish between 0s and 1s.



What does AUC = 0 mean?

Section 6

Summary

Summary

- Credit risk is inherent to business for most financial institutions
- Credit risk needs to be appropriately managed
- International standards has been developed in order to
  - Strengthen stability of the financial system
  - Provide a level-playing field for all financial institutions
- PD, LGD, EAD are key inputs for calculation of required capital
- PD can be estimated in a numer of ways, we focused on statistical analysis of historical data with various econometric and financial indicators
- Once a PD model is chosen and calibrated, its predictive power should be tested

References

[1] *Quantitative Risk Management*, Alexander J. McNeil, Rudiger Frey, Paul Embrechts, 2015

[2] *Risk Management and Financial Institutions*, John C. Hull, 2018

[3] *An Explanatory Note on the Basel II IRB Risk Weight Functions*, BCBS, 2005

Thank You

Good luck!

- Questions?