INSTITUTE OF ACTUARIAL & QUANTITATIVE STUDIES

Class: TY BSc

Subject : Financial Engineering – 2

Chapter: Unit 4 Chapter 2

Chapter Name: Credit Risk Analytics

Topics to be covered

1. Credit Risk
1. Outcomes of Defaults
1. Credit Events
1. Credit Risk Evaluation
1. Credit Ratings
1. Role of Credit Ratings
1. Credit Risk Classification
1. Default Risk

Continued ...

9. Recovery Risk
10. Exposure Risk
10. Exposure at Default
10. Expected Loss
10. Unexpected Loss
10. Expected Loss versus Unexpected Loss
10. Value at Risk (VaR)
10. Concentration Risk
10. Risk Adjusted Pricing

Continued ...

18. Merton Model

18. Two-State Model

18. Jarrow-Lando-Turnbull (JLT) Model

1 Credit Risk

- Credit risk changes with the market and good practice is to assess both current and potential exposure. The current exposure is the current market value of the asset, the future exposure should be based on a wide range of future scenarios, with different default probabilities.
- A credit loss only exists if the counter-party defaults and the contract has value. In a forward or swap contract, both long/receiving and short/paying parties are exposed to a credit risk, since either party could default if the market moves against them.
- For options and bonds, the purchaser of the option/bond is exposed to default by the writer/issuer, but they do not have an obligation to the writer/issuer.

- Credit risk is calculated as an expected loss:

Expected Loss = Exposure x Probability of Default x Loss Given Default

- All the parameters have an implicit time dependence. The Loss Given Default (LGD) is the percentage of the exposure that will be lost on a default, the recovery rate is the reciprocal of the LGD (Recovery Rate = 100%-LGD).
- Usually some value can be recovered when a counter-party defaults.

1 Credit Risk

Credit risk is the possibility of a **loss resulting from a borrower's failure to repay** a loan or meet contractual obligations. Traditionally, it refers to the risk that a lender may not receive the owed principal and interest, which results in an interruption of cash flows and increased costs for collection.

- Credit risk is usually ignored with respect to payments by a sovereign government in its own currency, but needs to be accommodated for if an obligation is met in a currency issued by a third-party (such as corporate obligations, obligations by a government in a currency it does not control).
- Corporate entities issuing bonds consist mainly of large companies and banks.

Example:

- In May 2014, Barclays had a 5¾% bond redeemable in September 2026 and Tesco had a 5½% bond redeemable in December 2019. These companies entered into a contract to make interest payments on set dates to the bondholders and to repay the face value of the bond on the redemption date. Failure to do this would result in the bonds being in default.

1 Example

- Assume Mr. Tony wants to purchase a car worth $120,000. He paid an amount of $20,000 as a down payment and decided to take a bank loan for the remaining amount of $100,000 at the rate of 20% per annum to be paid in 1 year.

- This means the bank needs to receive $120,000 back in a period of one year from Tony. The risk management of the bank checked Tony's credit risks before issuing the loan, i.e., the possibility that he might not be able to repay the loan or installments on the due date.

- With higher credit risks, Tony's loan application may get rejected by the bank, or the bank will allocate a lower sum of money that suits his credibility (ability to repay the loan) criteria. Tony, with a low credit risk count, gets the approval for loan allotment.

- Tony successfully paid a couple of installments of $10,000 each. But during the year, Tony made some big losses in his business due to offering goods on credit to customers with low credibility and applying liberal credit policies.

- The bank thinks Tony might not be able to make any further payments against the loan. The current situation creates huge risks to the bank against a loan provided to Tony.

2 Outcomes of defaults

- The outcome of a default may be that the contracted payment stream:
  - is rescheduled
  - is cancelled by the payment of an amount which is less than the default-free value of the original contract
  - continued but at a reduced rate
  - is totally wiped out.

3 Credit Events

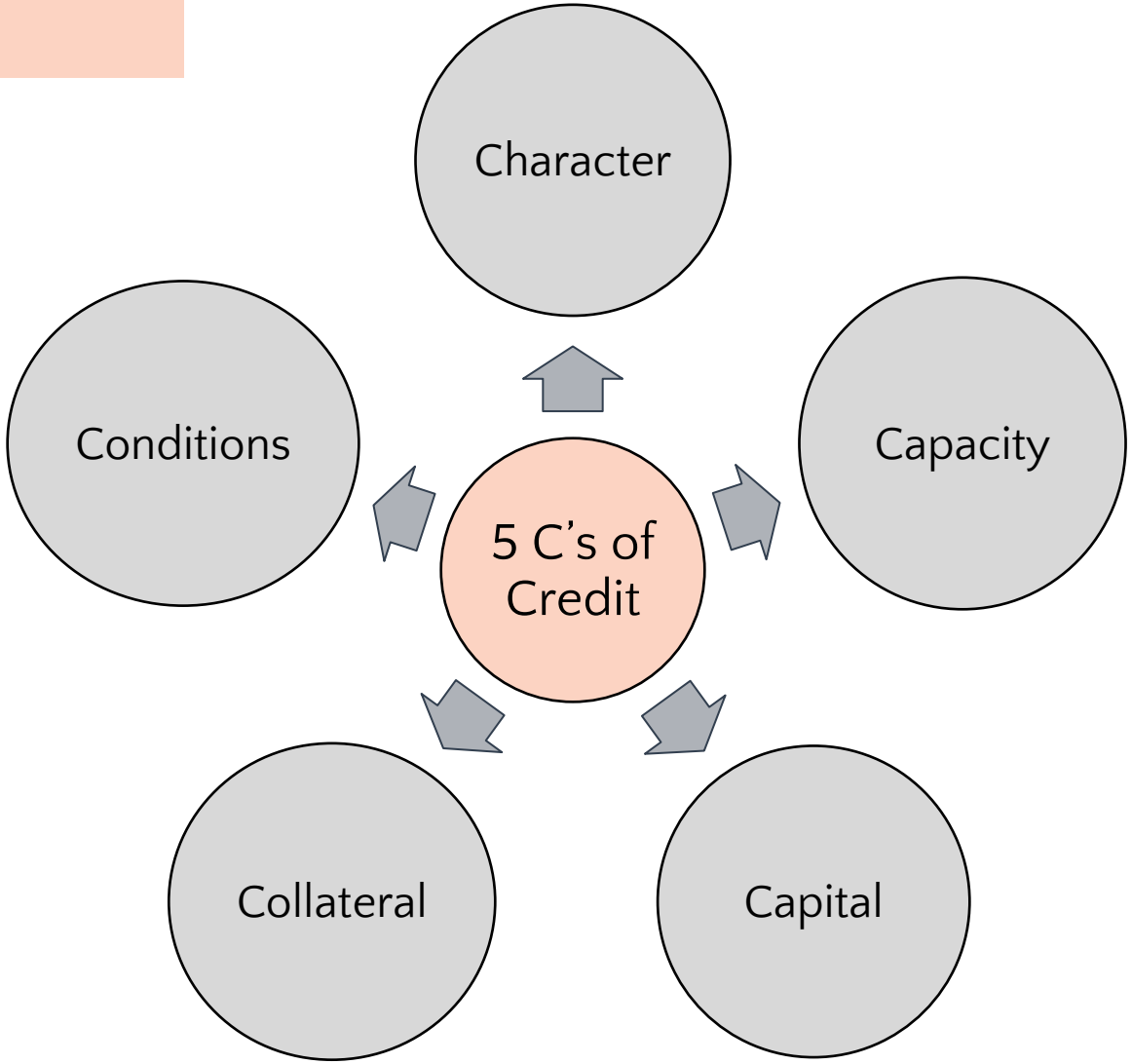
Credit events, which might result in a failure to meet an obligation (defined for the purposes of credit derivatives).

They include:

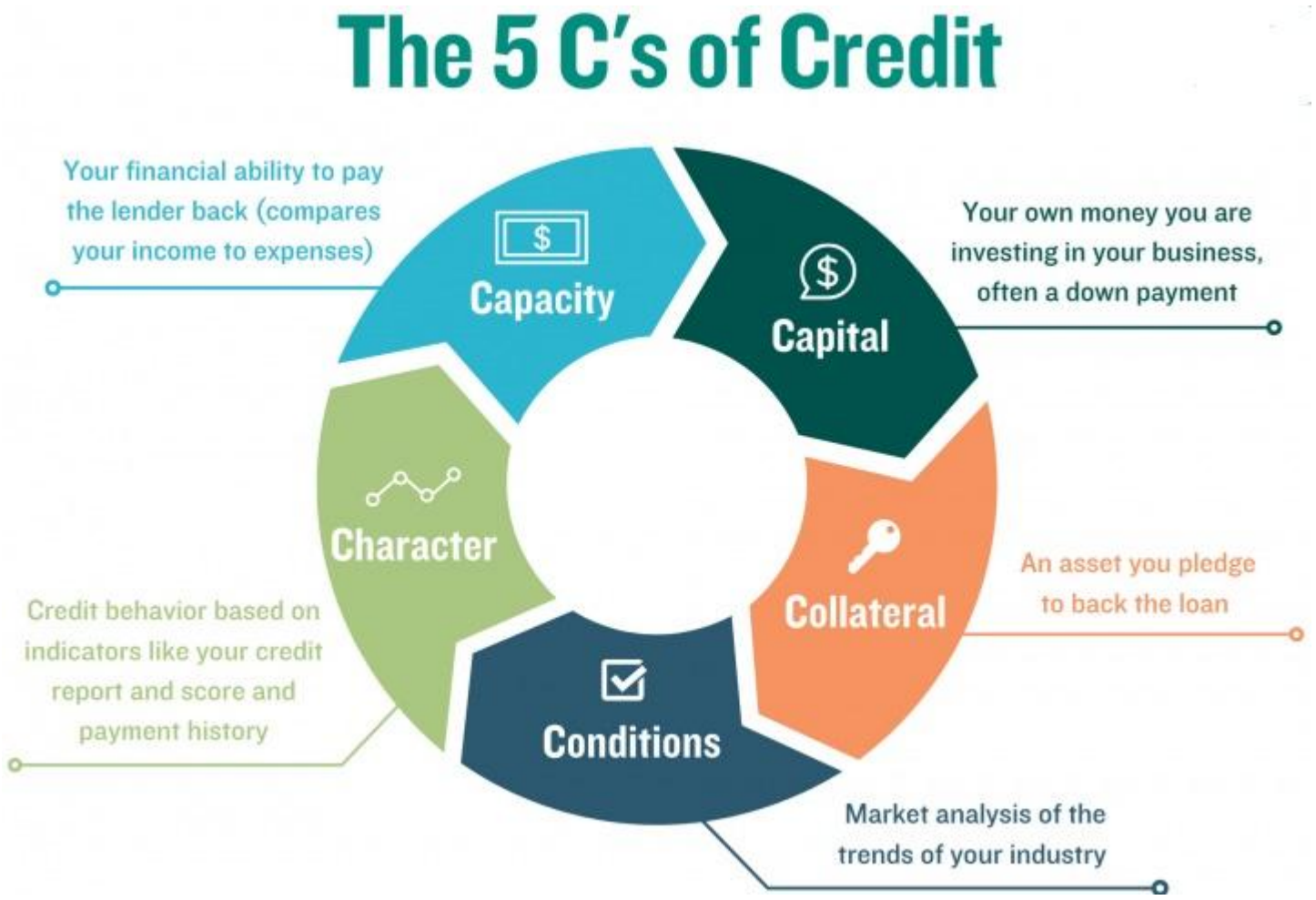
- actions that are associated with bankruptcy or insolvency laws: ie the bond issuer becomes insolvent.
- downgrade by 'Nationally Recognised Statistical Rating Organisations', (NRSROs such as Moody's, S&P and Fitch) This is of particular concern when a bond is issued with a guaranteed minimum credit rating.
- failure to pay: ie either a coupon or the capital amount is not paid in full and on time.
- repudiation / moratorium: ie the validity of the contract is disputed or a temporary suspension of activity is imposed on the issuer.
- restructuring – when the terms of the obligation are altered so as to make the new terms less attractive to the debt holder, such as a reduction in the interest rate, rescheduling, change in principal, change in the level of seniority.

4 Credit Risk Evaluation

- The five C's of credit is a system used by lenders to gauge the creditworthiness of potential borrowers. The system weighs five characteristics of the borrower and conditions of the loan, attempting to estimate the chance of default and, consequently, the risk of a financial loss for the lender.



4 Credit Risk Evaluation



5 Credit Ratings

Credit rating refers to a **quantified assessment of a borrower's creditworthiness** in general terms or with respect to a particular debt or financial obligation. A credit rating can be assigned to any entity that seeks to borrow money—an individual, a corporation, a state or provincial authority, or a sovereign government.

- Individual credit is scored by credit bureaus such as Experian, Equifax, and TransUnion on a three-digit numerical scale using a form of Fair Isaac Corporation (FICO) credit scoring.

- Credit assessment and evaluation for companies and governments is generally performed by a credit rating agency such as S&P Global, Moody's, or Fitch Ratings. These rating agencies are paid by the entity seeking a credit rating for itself or one of its debt issues.

6 Role of Credit Ratings

- Credit ratings for borrowers are **based on due diligence** conducted by the rating agencies. Though a borrowing entity will strive to have the highest possible credit rating because it has a major impact on interest rates charged by lenders, the rating agencies must take a balanced and objective view of the borrower's financial situation and capacity to repay the debt.

- A **credit rating determines** whether or not a **borrower will be approved for a loan** but **also the interest rate for the loan**. As companies depend on loans for many startup and other expenses, being denied a loan could spell disaster, and a high-interest-rate loan is much more difficult to pay back. A borrower's credit rating should play a role in determining which lenders to apply to for a loan. The right lender for someone with great credit likely will be different than for someone with good or even poor credit.

- Credit ratings **play a role in potential investor's decision as to whether or not to purchase bonds**. A poor credit rating is a risky investment because it indicates a larger probability that the company will be unable to make its bond payments.

- **Credit ratings are never static, which means borrowers must remain diligent in maintaining a high credit rating**. They change based on the newest data, and one negative debt will bring down even the best score. Credit also takes time to build up. An entity with good credit but a short credit history is not viewed as positively as another entity with equally good credit but a longer credit history.

6 Role of Credit Ratings

- Rating agencies **assess the credit risk of specific debt securities and the borrowing entities**. In the bond market, a rating agency provides an independent evaluation of the creditworthiness of debt securities issued by governments and corporations. Large bond issuers receive ratings from one or two of the big three rating agencies. In the United States, the agencies are held responsible for losses resulting from inaccurate and false ratings.

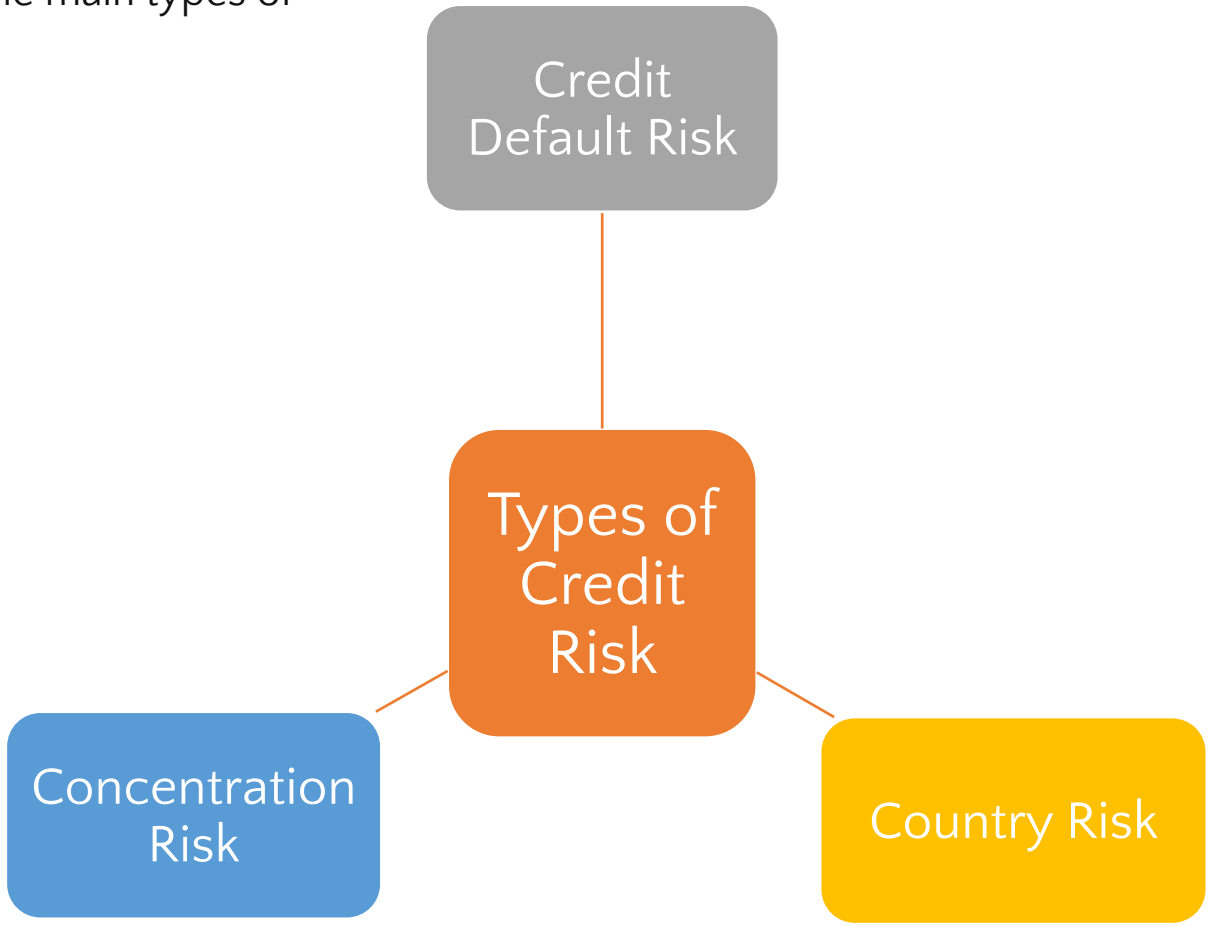
- The **ratings are used in structured finance transactions** such as asset-backed securities, mortgage-backed securities, and collateralized debt obligations.. The issuers of the structured products pay rating agencies to not only rate them, but also to advise them on how to structure the tranches.

- Rating agencies also **give ratings to sovereign borrowers**, who are the largest borrowers in most financial markets. Sovereign borrowers include national governments, state governments, municipalities, and other sovereign-supported institutions. The sovereign ratings given by a rating agency shows a sovereign's ability to repay its debt.

- The **ratings help governments** from emerging and developing countries **to issue bonds to domestic and international investors**. Governments sell bonds to obtain financing from other governments and Bretton Woods institutions such as the World Bank and the International Monetary Fund.

7 Credit Risk Classification

- The following are the main types of credit risks:



7 Credit Risk Classification

Credit Default Risk

- **Credit default risk occurs when the borrower is unable to pay the loan obligation in full or when the borrower is already 90 days past the due date of the loan repayment**. The credit default risk may affect all credit-sensitive financial transactions such as loans, bonds, securities, and derivatives.

- The level of default risk can change due to a broader economic change. It can also be due because of a change in a borrower's economic situation, such as increased competition or recession, which can affect the company's ability to set aside principal and interest payments on the loan.

7 Credit Risk Classification

Concentration Risk

- **Concentration risk is the level of risk that arises from exposure to a single counterparty** or sector, and it **offers the potential to produce large amounts of losses** that may threaten the lender's core operations. The risk results from the observation that more concentrated portfolios lack diversification, and therefore, the returns on the underlying assets are more correlated.

- For example, a corporate borrower who relies on one major buyer for its main products has a high level of concentration risk and has the potential to incur a large amount of losses if the main buyer stops buying their products.

7 Credit Risk Classification

Country Risk

- **Country risk is the risk that occurs when a country freezes foreign currency payments** obligations, resulting in a default on its obligations. The risk is associated with the country's political instability and macroeconomic performance, which may adversely affect the value of its assets or operating profits. The changes in the business environment will affect all companies operating within a particular country.

8 Default Risk

Default risk is the risk that a lender takes on in the chance that a borrower will be unable to make the required payments on their debt obligation.

- Whenever a lender extends credit to a borrower, there is a **chance that the loan amount will not be paid** back. The measurement that looks at **this probability is the default risk**. It applies to individuals who borrow money, and also to companies that issue bonds.

- Calculating the default risk of a borrower is crucial as part of its risk management strategy. Whenever an investor is evaluating an investment, determining the financial health of a company is crucial in gauging investment risk.

- **Default risk can change as a result of broader economic changes or changes in a company's financial situation.** Entities need to generate sufficient net income and cash flow to mitigate default risk.

- Default risk can be gauged using standard measurement tools, including FICO scores for consumer credit, and credit ratings for corporate and government debt issues. Credit ratings for debt issues are provided by nationally recognized statistical rating organizations (NRSROs), such as Standard & Poor's (S&P), Moody's, and Fitch Ratings.

9 Recovery Risk

Recovery risk refers to a company's exposure to loss as a result of damage to its ability to conduct day-to-day operations.

- Loss of ability to conduct day-to-day operations may result from supply chain interruptions, damage to physical locations, or loss of access to virtual systems, among other losses.

- Analysis of recovery risk involves categorizing threats according to short-, medium- and long-term impact. Short-term threats may include damage to computer systems or workers' inability to reach the job site due to natural disasters. Medium-term impact threats may include infrastructure failure or loss of staff. Long-term impact threats may include extensive property damage.

- Firms address business recovery risk within their business continuity plan (BCP). A BCP is created in order to ensure that personnel and assets are protected and able to function quickly in the event of a disaster.

- The BCP would create a system of prevention and recovery from potential threats. Risks may include natural disasters— such as fire, flood, or weather-related events—or cybersecurity attacks.

10 Exposure Risk

Exposure risk refers to the risk inherent in an investment, indicating the amount of money an investor stands to lose.

- For example, the financial exposure involved in purchasing a car would be the initial investment amount minus the insured portion. Knowing and understanding financial exposure, which is an alternative name for risk, is a crucial part of the investment process.

- The simplest way to minimize financial exposure is to put money into principal-protected investments with little to no risk. Certificates of deposit (CDs) or savings accounts are two ways to reduce financial exposure drastically.

- However, with no risk, an investment provides little return. Also, if there is little financial exposure, this leaves a conservative investor vulnerable to other risks such as inflation.

- Another way to reduce financial exposure is to diversify among many investments and asset classes. To build a less volatile portfolio, an investor should have a combination of stocks, bonds, real estate, and other various asset classes.

- When an investor diversifies their portfolio successfully among many asset classes, it should reduce overall volatility. If the market turns bearish, non-correlating asset classes will minimize the downside

11 Exposure at Default

Exposure at default (EAD) is the total value a bank is exposed to when a loan defaults.

- Using the internal ratings-based (IRB) approach, financial institutions calculate their risk. Banks often use internal risk management default models to estimate respective EAD systems. Outside of the banking industry, EAD is known as credit exposure.
- EAD is the predicted amount of loss a bank may be exposed to when a debtor defaults on a loan. Banks often calculate an EAD value for each loan and then use these figures to determine their overall default risk. EAD is a dynamic number that changes as a borrower repays a lender.
- There are two methods to determine exposure at default.
- Regulators use the first approach, which is called foundation internal ratings-based (F-IRB).
- The second method, called advanced internal ratings-based (A-IRB), is more flexible and is used by banking institutions. Banks must disclose their risk exposure. A bank will base this figure on data and internal analysis, such as borrower characteristics and product type.
- EAD, along with loss given default (LGD) and the probability of default (PD), are used to calculate the credit risk capital of financial institutions.

11 Exposure at Default

The Probability of Default and Loss Given Default

- PD analysis is a method used by larger institutions to calculate their expected loss. A PD is assigned to each risk measure and represents as a percentage the likelihood of default. A PD is typically measured by assessing past-due loans. It is calculated by running a migration analysis of similarly rated loans. The calculation is for a specific time frame and measures the percentage of loans that default. The PD is then assigned to the risk level, and each risk level has one PD percentage.
- LGD, unique to the banking industry or segment, measures the expected loss and is shown as a percentage. LGD represents the amount unrecovered by the lender after selling the underlying asset if a borrower defaults on a loan.
- An accurate LGD variable may be difficult to determine if portfolio losses differ from what was expected. An inaccurate LGD may also be due to the segment being statistically small. Industry LGDs are typically available from third-party lenders.
- Also, PD and LGD numbers are usually valid throughout an economic cycle. However, lenders will re-evaluate with changes to the market or portfolio composition. Changes that may trigger reevaluation include economic recovery, recession, and mergers.

- A bank may calculate its expected loss by multiplying the variable, EAD, with the PD and the LGD:

EAD x PD x LGD = Expected Loss

12 Expected Loss

- Expected Loss (EL) is a key credit risk parameter which assigns a numerical value between zero and one (a percentage) denoting the expected (anticipated) financial loss upon a credit related event (default, bankruptcy) within a specified time horizon.
- From a statistical perspective expected loss corresponds to the mean (average) of a Loss Distribution Function and is assessed on the basis of the historical loss experience (see also Unexpected Loss).
- Such losses, because they are expected, are provided for in the pricing of credits, with poorer credits attracting higher risk-spreads (and possibly other requirements to mitigate the credit risk such as collateral for instance) since their Probability of Default and their potential for Loss Given Default are higher.
- Credit risk spreads theoretically provide the basis for provisions for credit losses or loan loss reserves. Under older accounting and tax rules, most banks only set aside provisions/loss reserves on assets when the risk was clearly identified, only capturing part of the losses that can be expected over a loan portfolio's time horizon.

13 Unexpected Loss

- The worst-case financial loss and/or impact that a business could incur due to a particular Loss event or Risk realization. The unexpected loss is calculated as the Expected Loss plus the potential adverse volatility.
- Unexpected Loss is a formal Risk Measure that was introduced as part of the Basel II regulatory reforms. It is used primarily in the context of estimating Risk Capital using internal models and it aims to explicitly separate the related Expected Loss concept, (the idea being that expected losses are provisioned for and unexpected losses must be explicitly insured against with other forms of capital).
- Unexpected losses correspond to the unpredictable/unforeseeable losses that have a lower probability of occurrence but may nevertheless occur. Statistically, for a given confidence interval of the Loss Distribution Function, unexpected losses (UL) correspond to the difference between the maximum loss incurred and expected losses (EL).
- The original usage of the UL term was based on a volatility measure, this was gradually replaced by a quantile based measure. The quantile to which unexpected losses are computed is not consistent (or even explicit) throughout the regulatory framework

14 Expected Loss vs Unexpected Loss

- Expected Loss versus Unexpected Loss highlights a very general (and sometimes confusing) strategy in Quantitative Risk Management to decompose estimates of potential future Loss into an expected component (EL, Expected Loss)) and an uncertain element (UL, Unexpected Loss).

- A number of confusions may emerge from informal or ambiguous use of language:
  - The 'expectation' in Expected Loss does not imply a certain outcome
  - The expectation in Expected Loss does not mean the most likely outcome but the scenario average
  - The unexpected in Unexpected Loss can be captured by many different measures (e.g, quantile or other tail Risk Measure)

15 Value at Risk(VaR)

- Value at risk (VaR) is a statistic that quantifies the extent of possible financial losses within a firm, portfolio, or position over a specific time frame. This metric is most commonly used by investment and commercial banks to determine the extent and probabilities of potential losses in their institutional portfolios.
- Risk managers use VaR to measure and control the level of risk exposure. One can apply VaR calculations to specific positions or whole portfolios or use them to measure firm-wide risk exposure.
- VaR modeling determines the potential for loss in the entity being assessed and the probability that the defined loss will occur. One measures VaR by assessing the amount of potential loss, the probability of occurrence for the amount of loss, and the timeframe.
- This metric can be computed in several ways, including the historical, variance-covariance, and Monte Carlo methods.
- Investment banks commonly apply VaR modeling to firm-wide risk due to the potential for independent trading desks to unintentionally expose the firm to highly correlated assets.

16 Concentration Risk

- Concentration risk is the potential for a loss in value of an investment portfolio or a financial institution when an individual or group of exposures move together in an unfavorable direction. The implication of concentration risk is that it generates such a significant loss that recovery is unlikely. The portfolio will be liquidated or the institution will face bankruptcy.

- Generally, concentration risk is managed by concentration risk limits. There are many techniques for quantifying the concentration risk:
  - Use concentration indices (e.g., concentration portfolio, Gini coefficient, Herfindahl–Hirschman index, Hannah–Kay index, Hall–Tideman index, and Theil entropy index) to measure the level of concentration in the portfolio
  - Use transaction cost analysis to estimate market impact
  - Incorporate turnover constraints into portfolio analysis
  - Determine the impact from "what if" scenarios
  - Stress test the extreme events

17 Risk Adjusted Pricing

Risk adjusted pricing in the credit market refers to the offering of different interest rates and loan terms to different consumers based on their creditworthiness.

- Risk-based/adjusted pricing looks at factors associated with the ability of the borrower to pay back the loan, namely a consumer's credit score, adverse credit history (if any), employment status, income, dent level, assets, collateral, the presence of a co-signer, and so on.
- It does not consider factors such as race, color, national origin, religion, gender, marital status, or age which are not allowed according to local regulations.
- Lenders customize their risk-based pricing analysis to include specific parameters for borrower credit scores, debt-to-income, and other key metrics used for loan approval analysis.
- Lenders across the industry will have varying risk tolerances and loan risk management strategies. These strategies can dictate the parameters and borrower risks they are willing to take on.
- Risk-based pricing methodologies allow lenders to use credit profile characteristics to charge borrowers interest rates that vary by credit quality.
- This means that higher-risk borrowers who seem less likely to repay their loans in full and on time will be charged higher rates of interest while lower risk borrowers who seem to have a greater capacity to make payments will be charged lower rates of interest.

18 Merton Model

- The Merton model is a simple example of a structural credit-risk model.

- Classical finance defines the value of a firm *F(t)* as the sum of its debt, *B(t)* and equity *E(t)* , so:

$$F(t) = B(t) + E(t)$$

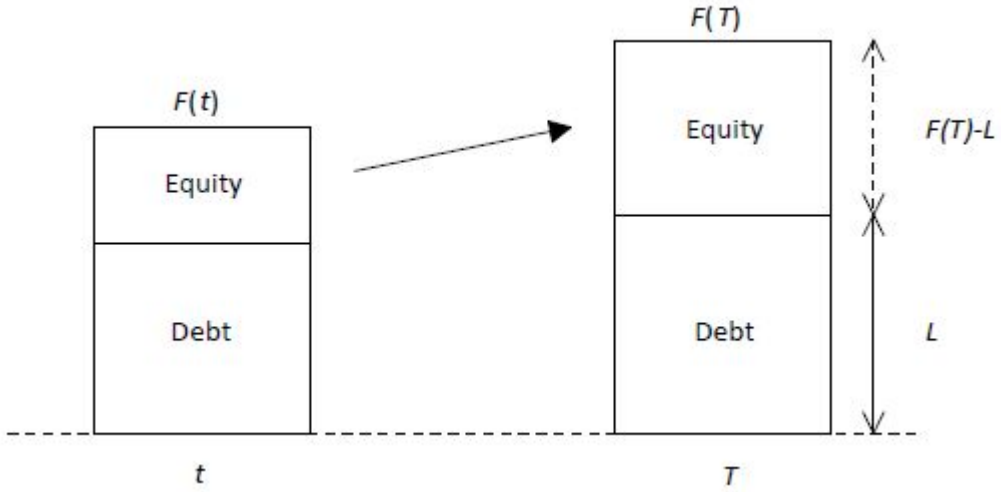
- Merton's model assumes that a corporate entity has issued both equity and debt such that its total value at time t is *F(t)*. This value varies over time as a result of actions by the corporate entity, which does not pay dividends on its equity or coupons on its bonds.
- For example, the value of a company will change along with investors' perceptions of the future prospects of that company.
- Assume a firm has issued a single zero-coupon bond with face value of *L* which matures at time T.
- Debt holders rank above shareholders in the wind-up of a company. So, provided the company has sufficient funds to pay the debt, the shareholders will receive *F(T) - L* .

18 Merton Model

- The corporate entity will default if the total value of its assets, *F(T)* , is less than the promised debt repayment at time *T* :

  ie *F(T) < L*

- In this situation, the bondholders will receive *F(T)* instead of L and the shareholders will receive nothing.
- Combining these two cases, we see that the shareholders will receive a payoff of max*{F(T)-L,0}* at time *T*.



- This can be regarded as treating the shareholders of the corporate entity as having a European call option on the assets of the company with maturity *T* and a strike price equal to the value of the debt. The Merton model can be used to estimate either the risk-neutral probability that the company will default or the credit spread on the debt.
- Since debt is senior to equity, the value of equity at maturity:

$$E(T) = \max\{F(T) - L, 0\}$$

- and so the value of a firm's equity is a call option on the value of the firm with a strike of the debt.

18 Example

Company X has the following financial structure at time 0:

Debt	3 million pound (current book value)
Equity	6 million pound (issued share capital)

The debt is a zero-coupon bond with face value £5m that is repayable at par at time 10.
There are 400,000 shares in circulation.

i. Explain how the Merton model could be used to value shares in Company X.
ii. Assuming that the debt is repaid directly from the company's funds at that time, state the share price at time 10 if the total value of Company X at that time is:
    a. 15 million pound
    b. 4 million pound

18 Example

Solution:

i. Expressing the equity as a call option

The Merton model values shares as call options on the company's assets with a strike price equal to the face value of Company X's debt.

The equity value at time 10 will be:

$$\max\{F(10) - 5, 0\}$$

Where *F(10)* = Total value of Company X at time 10.

Company X will default on payment of the debt if the total value of its assets at time 10 is less than the promised debt repayment at that time.

There are 400,000 shares, so the (theoretical) share price at time 10 in £m will be:

$$\frac{\max\{F(10) - 5, 0\}}{400,000}$$

An appropriate option pricing formula can then be used to value this 'call option' at time 0.

ii. Share price at time 10

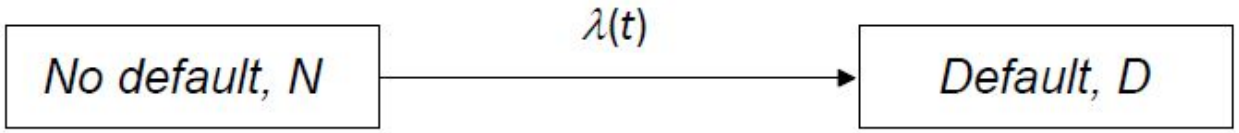
a. The share price at time 10 will be:

$$\frac{\max\{15 - 5, 0\}}{400,000} = \frac{10\ million\ pound}{400,000} = 25\ \text{pounds per share}$$

b. Here the share price at time 10 will be 0 because the value of the outstanding debt exceeds the total value of the company.

19 Two-State Model

- We will now consider a two-state intensity-based model, which is the simplest continuous-time reduced-form model.
- A model can be set up, in continuous time, with two states:
  1. N = not previously defaulted
  2. D = defaulted.
- If the transition intensity, under the risk-neutral measure Q , from N to D at time t is denoted by $\lambda(t)$, this model can be represented as:



- and D is an absorbing state.
- This is a two-state continuous-time Markov model. It has the same structure as the two-state mortality model, with 'No default' corresponding to 'Alive', 'Default' corresponding to 'Dead' and $\lambda(t)$ corresponding to the force of mortality.

20 Jarrow-Lando-Turnbull(JLT) model

- In this n-state model, transfer is possible between all states except for State *n* (default), which is absorbing. If *X(t)* is the state or credit rating at time *t* , then, for i=1,2,..,n-1, the transition probabilities over the time interval *(s,t)* are:

  $q_{ij}(s.t) = Q(X(t) = j|X(s) = i)$ for t>s
- The matrix of transition probabilities is:

  $Q(s,t) = \left(q_{ij}(s,t)\right)_{i,j-1}^{n}$
- Then:

  $Q(s,t) = \exp[\int_s^t \Lambda(u)du]$
- Where:

  $\Lambda(t) = \left(\lambda_{ij}(t)\right)_{i,j-1}^{n}$

  is the matrix of transition intensities.