Credit Risk and Credit Derivatives

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PART I - CREDIT RISK

Definition

Credit risk is dispersion in financial outcomes associated with the failure or potential failure of a counterparty to fulfill its financial obligations.

Overview

- **Default risk** is the risk that the issuer of a bond or the debtor on a loan will not repay the interest and principal payments of the outstanding debt in full.
- A debtor is deemed to be **in default** when it fails to make a scheduled payment on its outstanding obligations.
- **Credit risk** is influenced by:
  - macroeconomic events
  - company-specific events
  - liquidity crisis

Credit risk management

- Credit risk emanates from the structuring of cash flows. Cash flows are promised but are backed by an uncertain ability to meet those contractual obligations. Financial institutions and investors who have substantial exposure to credit risk look for effective ways to measure and manage their credit risk exposures consistently and accurately. This has led to a growing body of knowledge regarding **credit models**.

- Credit models can be divided into two groups:
  - Structural models
  - Reduced-form models

Structural models

- **Structural credit risk models** use option theory to explicitly take into account credit risk and the various underlying factors that drive the default process:
  - the behaviour of the underlying assets
  - the structuring of the cash flows (debt levels)
- Directly relate valuation of debt securities to financial characteristics of the economic entity that has issued the credit security. These factors include firm-level variables, such as:
  - debt-to-equity ratio
  - volatility of asset values
  - cash flows

Merton's Structural model

- The key to Merton's approach is to recognise the option-like characteristics of structured cash flows.
- The **call option view of capital structure** views the equity of a levered firm as a call option on the assets of the firm:
  - If its asset value is less than its debt the shareholders can declare bankruptcy.

Due to the put-call parity, a call option can be viewed as a long position in a put option and the underlying assets financed with a riskless bond. As such:
Asset = Riskless Bond - Put + Call

Valuing Risky debt

- Consider a change of anticipated volatility of the firm's assets that leaves the current value of the firm's asset unchanged.
  - The value of the equity increases as the call value increases
  - The value of the put increases, hence the value of the debt decreases.
- To estimate the value of debt that contains credit risk, we can:
  - Estimate the volatility of the firm
  - Unlever the firm's estimated equity volatility based on its capital structure: $\sigma_{assets} \approx \sigma_{equity} \frac{Equity}{Assets}$
  - Solve for the price of a call and put on the firm's assets
  - Value the firm's debt

Advantages structural model applications

- The structural approach tends to rely on data from equity markets, e.g. observed stock price and/or implied volatilities. Since equity markets are generally more liquid than corporate bond markets, equity markets provide more reliable information than credit markets provide.
- Structural models are well suited for handling different securities of the same issuer.

Disadvantages of structural model applications

- Not adapted to value complex derivative products
- If equity prices are highly unreliable, than estimates of asset volatility and values are also highly unreliable.
- Current data on a firm's or structure's liabilities may be unreliable.
- The valuations generated by simple structural models are sometimes unreasonable, especially for short-term, very high-quality debt and for debt near default.

Reduced-form credit models

- Reduced-form credit models do not attempt to look at the structural reasons for default risk but focus on **default probabilities** based on observations of market data of similar-risk securities.
- Reduced-form approaches model the observed relationship among yield spreads, default rates, recovery rates and frequencies of rating changes throughout the market.
- The key feature of reduced-form credit models is that **credit risk** is understood through analysis and observation of market data from similar credit risks rather than through the underlying structural details of the entities, such as amount of leverage.

Advantages of Reduced-form models

- They can be calibrated using derivatives such as CDS, which are highly liquid.
- They are extremely tractable and well suited for pricing derivatives and portfolio products.
- The models can rapidly incorporate credit rating changes and can be used in the absence from balance sheet information.

Disadvantages of Reduced-form models

- They may be limited reliable market data with which to calibrate a model.
- They can be sensitive to assumptions, particularly those regarding the recovery rate.
- Information on actual historical default rates can be problematic.
- Few observations are available for defaults by major firms or sovereign states.

Markets

- There are two markets for trading financial instruments:
  - **Exchange-traded market**
  - **Over-the-counter (OTC) market**
- Exchange-traded markets:
  - The role of exchange is to define the contracts that trade and organise trading so that market participants can be sure that the trades they agree to will be honoured:
  - Exchange-traded derivative contracts are:
    - Administered by a **clearing house**:
      - Step between buyers and sellers to take counterparty risk
      - member firms post **margin** as collateral
    - Standardised

OTC Markets

- Huge network of traders who work for financial institutions, large corporations or fund managers.
- Market participants are free to negotiate any mutually attractive deals
- Market participants face **counterparty credit risk**, i.e. risk that a counterparty in a derivative instruments will default prior to expiration of the trade.
  - To mitigate counterparty credit risk:
    - Netting
    - Collateral
    - Diversification
    - Hedging

Estimation of default probabilities with structural models

- Mertons' structural model is typically used to estimate the probalility of default (PD) of small and illiquid companies that are not rated by agencies:

  - These companies usually do not have complex structured products and a simple debt structure.
  - Given the financial statement of the company, the leverage ratio is known.
  - The debt can be valued by estimating the equity as a call option.

Estimation of default probabilities with reduced-form models

- Default probabilities are estimated:
  - from historical data of actual default using logistic regressions:
    - For large and medium size companies, rating agencies such as Moody's, S&P and Fitch provide credit ratings and historical PDs
    - For small companies without credit ratings, PDs are estimated with logistic regressions based on the main default drivers of small companies.
  - from observable **credit spread** of CDS, bonds and option on common stocks
  - popular statistical methods include:
    - linear regression, such as the Altman's Z-score
    - Survival models:
      - Cox proportional hazards model
      - Poisson regression models

Counterparty Risk

- **Counterparty risk** is the risk that a party to an OTC derivatives contract may fail to perform on its contractual obligations, causing losses to the other party.
- Losses are usually quantified in terms of the replacement cost of the defaulted derivatives and include, beyond mid-market values, the potential market impact of large and/or illiquid positions
- Counterparty risks are bilateral:

- both parties may face exposures depending on the value of the positions they hold against each other.

Counterparty Exposures

- **Counterparty exposure** at any given future time is the larger between zero and the market value of the portfolio of derivative positions with a counterparty that would be lost if the counterparty were to default with zero recovery at that time: $Exposure = \max\{MtM; 0\}$
- **Current exposure (CE)** is the current value of the exposure to a counterparty.

Mitigation Counterparty Exposures

- Mitigating counterparty exposure can be achieved through:
  - Netting agreements
    - In the presence of **multiple trades** with a counterparty, **netting agreements** allow, in the event of default of one of the counterparties, to aggregate the transactions before settling claims. $Exposure_{netting}(t) = \max\{\sum_{i=1}^{n} w_i MtM(t); 0\}$ where w_i is asset quantities
  - Collateralisation
    - A **collateral account** is a contractual clause aimed at reducing potential losses incurred by investors in case of the default of the counterparty, while the **contract is still alive**.
      - Let $C(t)$ be the collateral amount at time t. The exposure in presence of collateral is $Exposure_{collateral}(t) = \max\{E(t) - C(t); 0\}$

Collateral

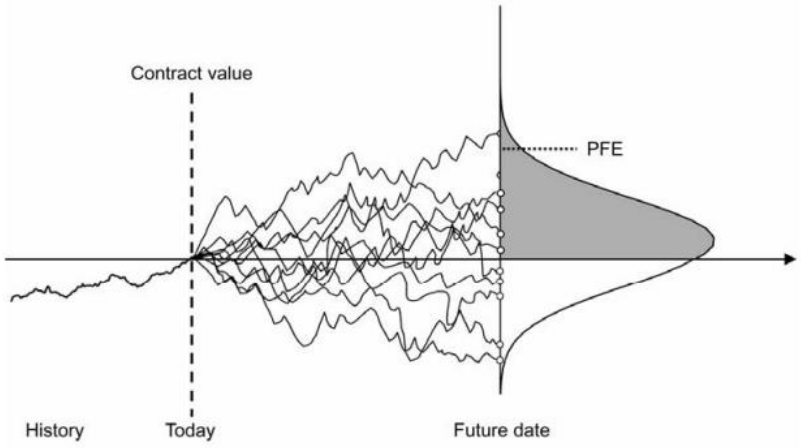
- **The actual amount of the collateral** available at time t depends on the contractual agreement between the parties (typically defined in the **Credit Support Annex (CSA)**), specified in terms of:
  - Posting **threshold** $H > 0$:
  - **Margin period** δ:

    - the interval at which margin is monitored and called for: $C(t) = \max\{Exposure(t-\delta) - H; 0\}$
  - **Minimum Transfer Amount (MTA)**:
    - if the amount of collateral falls under a **maintenance margin**, collateral needs to be posted: $C(t) = \max\{Exposure(t-\delta) - H; 0\}1_{Exposure(t-\delta)-H>MTA}$
  - **Downgrade trigger**:
    - the CSA can specify a **rating-based collateral calls**, which forces a firm to post more collateral it it is downgraded below a given level.

Potential Future Exposure (PFE)

Potential Future Exposure (PFE) is the maximum amount of exposure expected to occur on a future date with a high degree of statistical confidence.

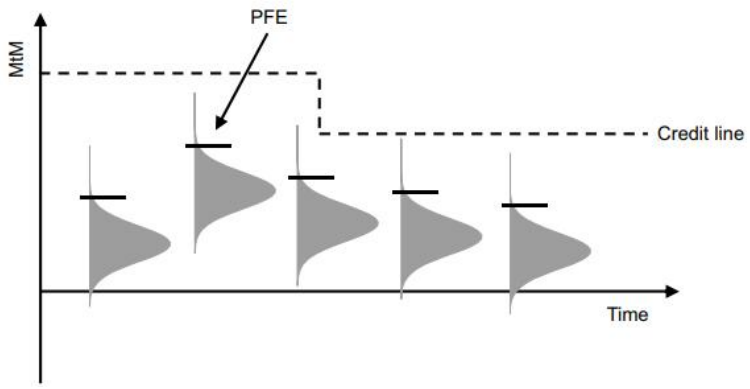
- For example, the 95% PFE is the level of potential exposure that is exceeded with only 5% probability.
- The curve of PFE in time is the potential exposure profile, up to the final maturity of the portfolio of trades with the counterparty.



Maximum Potential Future Exposure (MPFE)

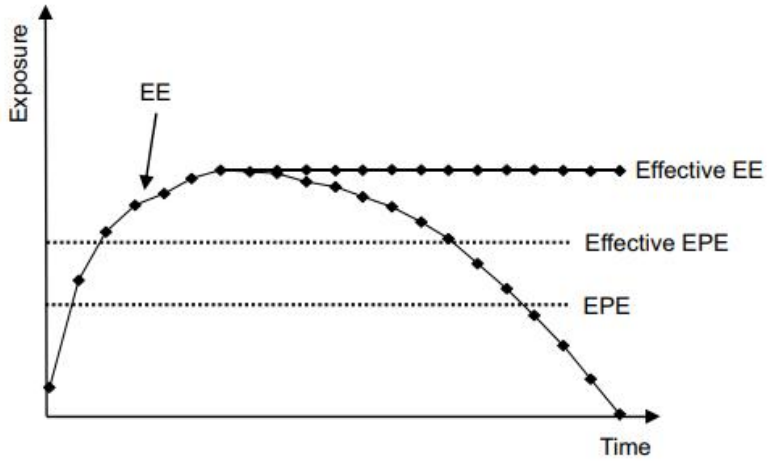
- The **maximum potential future exposure (MPFE)** represents the peak of PFE over the life of the portfolio. PFE and MPFE are used

to determine **credit lines**.



Exposure Profiles

- **Expected exposure (EE)** is the average exposure on a future date. The curve of EE in time, as the future date varies, provides the expected exposure profile.
- **Expected positive exposure (EPE)** is the weighted average EE in time until t.



- **Effective Expected exposure (EEE)** is the maximum expected exposure until t.
- **Effective expected positive exposure (EEPE)** is the weighted average EEE until t.

Credit Valuation Adjustment (CVA)

- The **credit valuation adjustment (CVA)** of an OTC derivatives portfolio with a given counterparty is the market value of the credit risk due to any failure to perform on agreements with that counterparty.
- In other word, CVA is the **difference between the risk-free value and the risky value** of one or more trades:

  Given the time t NPV of a derivative $E_t[\Pi(t,T)]$ where $\Pi(t,T)$ and $\Pi^D(t,T)$ represent the sum of all cash flows between T and t, without and in presence of counterparty risk, respectively. The CVA is:

$$CVA := E_t[\Pi(t,T)] - E_t[\Pi^D(t,T)] \tag{1}$$

- the **unilateral CVA** only considers the default of the counterparty.
- the **bilateral CVA** also takes into account the default of the investor (self).

Unilateral CVA

The **unilateral CVA** is defined as:

$$CVA(t,T) = (1-R)E_t[\max\{MtM(\tau);0\}1_{\tau\leq T}P(t,\tau)] \tag{2}$$

where

- $t < \tau < T$ is the **default event**
- $1_{\tau\leq T}$ is the default probability of the counterparty before T
- $P(t,\tau)$ the discount factor between τ and t.

Bilateral CVA

The **bilateral CVA** takes into account the DVA of the investor (self) is given as:

$$\begin{aligned} CVA(t,T) &= MtM(t) \\ &- (1-R_c)E_t[\max\{MtM(\tau_c);0\}P(t,\tau_c)1_{\tau_c\leq T}1_{\tau_c\leq\tau_{self}}] \\ &+ (1-R_{self})E_t[\min\{MtM(\tau_{self});0\}1_{\tau_{self}\leq T}1_{\tau_{self}\leq\tau_c}P(t,\tau_{self})] \end{aligned} \tag{3}$$

where

- R_c and R_{self} is the recovery rate of the counterparty and the investor, respectively.
- τ_c and τ_{self} are the default event of the counterparty and the investor, respectively.

Wrong-way Risk

- The computation of CVA assumes that the probability of default is independent of the exposure. In reality, the default probability is often positively correlated with the exposure profile.
- CVA can be corrected to take into account **wrong-way risk**. Three approaches have been proposed:
  - regulatory
  - Correlation
  - Stress-testing

Credit Value at Risk

- **Credit risk VaR** is defined similarly to market risk VaR. It is the credit risk loss over a certain time period that will not be exceeded with a certain confidence level.
- Banks calculate credit risk VaR to determine both regulatory capital and economic capital
- The time horizon for credit risk VaR is often longer than that for market risk VaR. Market risk VaR is often calculated with a one-day time horizon.
- Counterparty defaults are not independent, especially in **economic downturn**.
- The **credit correlation** is estimated with **Ratings Transition Matrices** provided by Moody's, S&P and Fitch. It estimates the probability of one company to migrate from one rating category to another one

Credit Value at Risk - regulatory capital

- Vasicek's Gaussian copula model as specified in Basel II's Internal Rating-Based (IRB) approach to estimate credit risk in the banking book.
- It is a way of calculating the X^{th} percentiles of the distribution of the default rate of a portfolio of N loans:
  - $WCDR(T,X) = \mathcal{N}(\frac{\mathcal{N}^{-\infty}(PD)+\sqrt{\rho}\mathcal{N}^{-\infty}(X)}{\sqrt{1-\rho}})$
  - The X^{th} percentile of the loss distribution of a portfolio of N loans is $\sum_{i=1}^{n} WCDR_i(T,X) \times EAD_i \times LGD_i$
  - Banks typically implement their own method to estimate the probability of default and credit correlation ρ but use IRB's method to estimate LGD and EAD.

PART II - CREDIT DERIVATIVES

Credit Derivatives Markets

- **Credit derivatives** transfer the default risk from a buyer of credit protection to a seller of credit protection.
- Provide a cost-effective solution for banks to hedge credit risk:
  - to make large loans to a firm while transferring default risk to other market participants
  - keep a well-diversified portfolios of credit risks while maintaining efficient and effective relationships with key clients.
- Provide **liquidity** to the market in time of credit stress
- Provide ongoing and reliable **price revelation** and, therefore, enhance overall economic efficiency

Single-name versus Multiname instruments

- **Single-name credit derivatives** transfer the credit risk associated with a single entity:
  - Most single-name credit derivatives are credit default swaps (CDSs)

- **Multiname instruments** make payoffs that are contingent on one or more credit events (e.g. defaults) affecting two or more reference entitites:
  - first-to-default CDS
  - CDX
  - iTraxx

Unfunded versus Funded instruments

- **Unfunded credit derivatives** involve exchanges of payments that are tied to a notional amount, but the notional amount does not change until a default occurs,
  - CDS
  - Total Return Swaps (TRS)
- **Funded credit derivatives** requires cash outlays and credit exposures
  - Credit-linked notes

Sovereign versus Non-Sovereign entities

- Credit derivatives on sovereign nations have not only to consider the possible **inability** of a nation to meet its obligations but also the possible **unwillingness** of a nation to meet its obligations.
- Sovereign CDS need to model:
  - political risk
  - macroeconomic risks

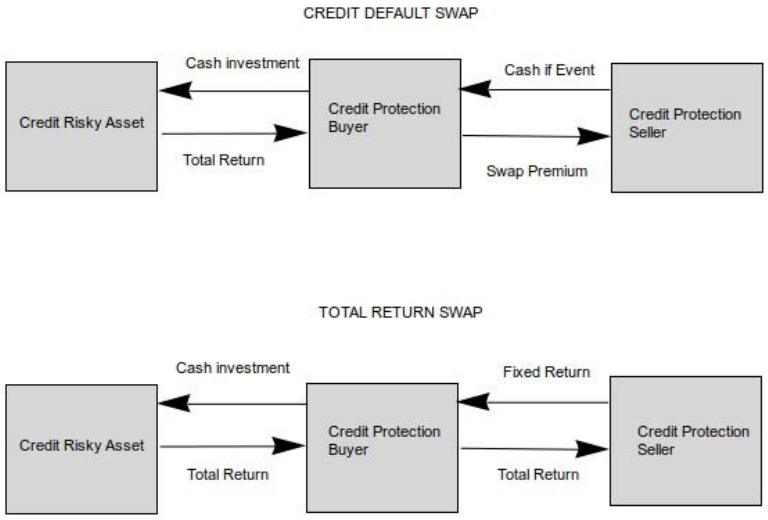
Credit Default Swaps

- A **credit default swap (CDS)** is an insurance-like bilateral contract in which the buyer pays a periodic fee to the seller in exchange for a contingent payment from the seller if a credit event occurs with respect to an underlying credit-risky asset.

  - Can be negotiated on variety of credit-risky instruments, primarily corporate bonds.

- A **total return swap (TRS)** is an insurance-like bilateral contract in which a credit protection buyer passes on the total return of an asset to the credit protection seller in return for a certain payment.
  - The credit protection seller receives both the upside and the downside of the return associated with the credit-risky asset.

CDS and TRS



Mechanics of CDS

- The CDS market is contract driven: each CDS is a privately negotiated transaction between a credit protection buyer and a credit protection seller.
- **ISDA** has establised standardised terms for CDSs specifying:
  - CDS Spread

- Contract size (typically between $20m and $200m) with a tenor of 3-5 years.
- Trigger events: Bankruptcy, Failure to pay, restructuring, obligation acceleration (accelerate payment if credit quality deteriorates), obligation default
- Settlement: cash or physical
- Delivery: cheapest to deliver

Credit Options

- Credit options on risky bonds and on credit spread are traded OTC.
- **Credit Binary options** offer only two possible payouts, usually zero and some other fixed value.
- A put option on risky bond is typically exercised if the bond experiences a credit event, such as a default:

$\max\{X - B(t); 0\}$ in default and 0 otherwise
where X is the strike price of the put option and $B(t)$ is the market value of the bond at default.

- Combined with the underlying bond, a credit put option offers the full repayment of the bond's principal if no credit event occurs and the payment of the put in default.

Call option on CDS

- A call option on CDS allows the holder of the call to enter a CDS at the rake (strike) specified in the option contract.
- Allows a buyer to only buy credit protection if the spread widens, i.e. if credit worthiness of the bond issuer deteriorates.

Credit Linked Notes

- **Credit-linked notes (CLNs)** are bonds issued by one entity with an embedded credit option on one or more other entities.

- The CLN is like a CDS in that it is engineered to have payoffs related to the credit risk of a firm while beying legally distinct from that firm.
- The holder of a CLN receives a periodic coupon and then the par value of the note at maturity if there is no default on the underlying referenced corporation or basket of credits.
- In default, downgrade or adverse credit event, the holder of the CLN receives a lower coupon payment or only a partial redemption of the CLN principal value.
- The long position in a CLN bears credit risk without being part of any bankruptcy.

CDS Index Products

- **CDS indices** are indices or portfolios of single-name CDSs.
- They allow investors to take long or short positions on baskets of credits.
- Developed globally under the banner:
  - CDX in North America and emerging markets
  - iTraxx in Europe and Asia
- Encompasses all major corporate bond markets in the world:
  - CDX and iTraxx indices consists of 125 credit names
  - highly liquid
- The protection buyer pays a fixed premium, typically on a quarterly basis.
- The protection seller pays for credit events on each and every credit risk in the index.

CDO Structuring of Credit Risk

- **Collateralised debt obligation (CDOs)** are structures that partition the risk of a portfolio into ownership claims called **tranches**, which differ in seniority:

  - A **senior tranche** is a tranche with the first or highest priority to cash flows in the structured product.
  - **mezzanine tranches** have moderate priority to cash flows and with lower priority than the senior tranche.
  - **equity tranche** has the lowest priority and serves as the residual claimant.

- The key point of a CDO is to engineer the risk of a portfolio into a spectrum of risks tailored to meet the needs, preferences and market views of various investors.

General Structure of CDOs

- At the centre of every CDO structure is a **special purpose vehicule (SPV)**:
  - legal entity which holds the collateral portfolio
  - the SPV owns the collateral placed in the trust and issues notes and equity (tranches) against the collateral it owns.
  - the SPV is **bankruptcy remote**, as the CDO trust is not affected by the default of the sponsoring bank

- Each tranche has its own credit rating.
  - typically, all tranches besides the equity trade have investment-grade rating recognised by statistical rating organisations
  - the equity tranche, also called the first-loss tranche, is the first tranche on the hook for any defaults or lost value of the CDO collateral.

CDO - Risk and Return

- The risk and return of the **reference portfolio**, i.e. pool of assets held in the SPV within the CDO structure are described using:
  - **Weighted average rating factor (WARF)**: Moody's numerical scale estimating the probability of default of each asset.
  - **diversity score**: numerical estimation of the extent to which a portfolio is diversified.

  - **Weighted average spread (WAS)**: Weighted average of the return spreads of the pool of assets.

- The **tranche width** is the percentage of the CDO's capital structure that is attributable to a particular tranche.

Balance sheets and Arbitrage CDOs

- Financial institution typically issue **Balance sheet CDOs** to divest assets from their balance sheet:
  - Remove a portion of a bank's loan portfolio from its balance sheet:
    * to reduce its credit exposure
    * to get a much-needed capital infusion
    * to reduce its regulatory capital charges

- **Arbitrage CDOs** are designed to make a profit by capturing a spread for the equity investors in the CDO and by earning fees for money management services.
  - A profit is made if the CDO trust can issue its tranches at a yield substantially lower than the yield earned on the bond collateral contained in the trust.

Cash-funded and Synthetic CDOs

- A **cash-funded CDO** involves the actual purchase of the portfolio of securities serving as the collateral for the trust and to be held in the trust
  - The physical ownership of the assets is acquired by the CDO.

- In a **synthetic CDO**, the CDO obtains risk exposure for the collateral pool through the use of credit derivatives, such as TRS or CDS.
  - The physical ownership of the underlying basket of securities is not transferred to the CDO.

Collateralised mortgage obligation

- CDOs on mortgage assets are called **Collateralised mortgage obligations (CMOs)**
- CMOs are used to transfer uncertainty of insured mortgages with regards to timing and size of prepayments.
- The issuer of the CMO receives the monthly mortgage payments (principal + interest) from the collateral pool and passes the payment on to the various tranches.
- Each tranche has a coupon and a prespecified priority in receiving distributions of principal payments.
  - In the case of **insured residential mortgages**, the structuring of the cash flows focuses on maturity and cash flow timing.
  - In the case of **commercial mortgages** and **subprime residential mortgages**, the focus is on the allocation of default losses.

Structuring of Sequential-Pay CMOs

- In a **sequential-pay CMO**, each tranche receives a prespecified share of the interest payments based on each tranche's coupon and principal amount. Each tranche also potentially receives a principal.
- The first-pay tranche (senior tranche) receives all principal repayments until the tranche's face value has been fully repaid. A tranche matures once it has received repayment of its entire principal value.
- The next senior tranche then receives the entire principal payments until it, in turn, matures.
- The most junior tranche, called the **Z-tranche**, receives any residual cash flows.

Other CMO structures

- Investors in **Planned amortisation class (PAC)** tranches have high priority for receiving principal payments as long as the prepayment rates are within a prespecified range.

- **Targeted amortisation class (TAC)** receive principal payments in a manner similar to PAC tranches but generally with an even narrower and more complex set of ranges.
- **Principal-only (PO)** tranches receive only principal payments from the collateral pool, whereas **interest-only (IO)** tranches receive only interest payments from the collateral pool:
  - PO tranches are exposed to **extension risk** (value declines when prepayment slows)
  - IO tranches are exposed to **contraction risk** (value decline when prepayment accelerates)