An Introduction to Credit Risk

QF622 Credit Risk Models

Nanfeng SUN

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Practicalities

Who am I?

- Trained as an engineer, with a PhD in Chemical Engineering
- Having worked in London, Hong Kong and Singapore
- Having worked as a practitioner as well as a regulator
- Started as a risk quant at Deutsche Bank, working on CDOs
- Regional head of model risk at Bank of America in Asia Pacific
- Technical lead for internal models at the Securities and Futures Commission, the markets regulator in Hong Kong
- Head of Market & Counterparty Risk Analytics at DBS Bank

The usual disclaimer

The opinions shared during this course are solely those of my own and not necessarily those of my current and former employers.

What to expect?

You will

- understand what credit risk is and where it originates from
- familiarise with the range of traded credit products
- study canonical models for pricing credit products
- learn the basics of counterparty credit risk (CCR) modelling
- get a general picture of post-GFC regulatory reform on CCR

You are encouraged to

- stay focused and pay attention
- ask many questions as no question is dumb

Course overview

Lectures

1. Introduction to Credit Risk
2. Single-Name Models and Products
3. Multi-Name Models and Products
4. Counterparty Credit Risk and Exposure Modelling
5. Post-GFC Reforms: Clearing, Margining and Capital

Grading

Exam : Assignments : Participation = 50% : 40% : 10%

Contact

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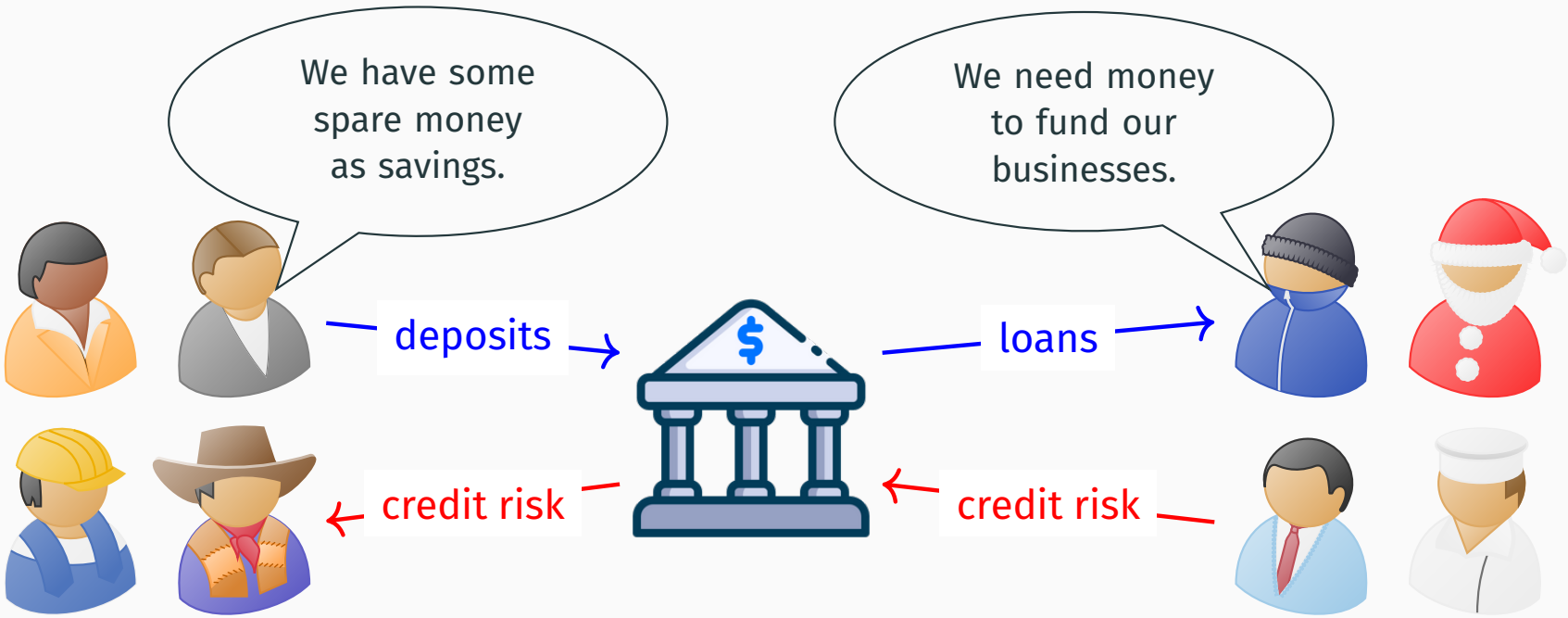
Recommended reading

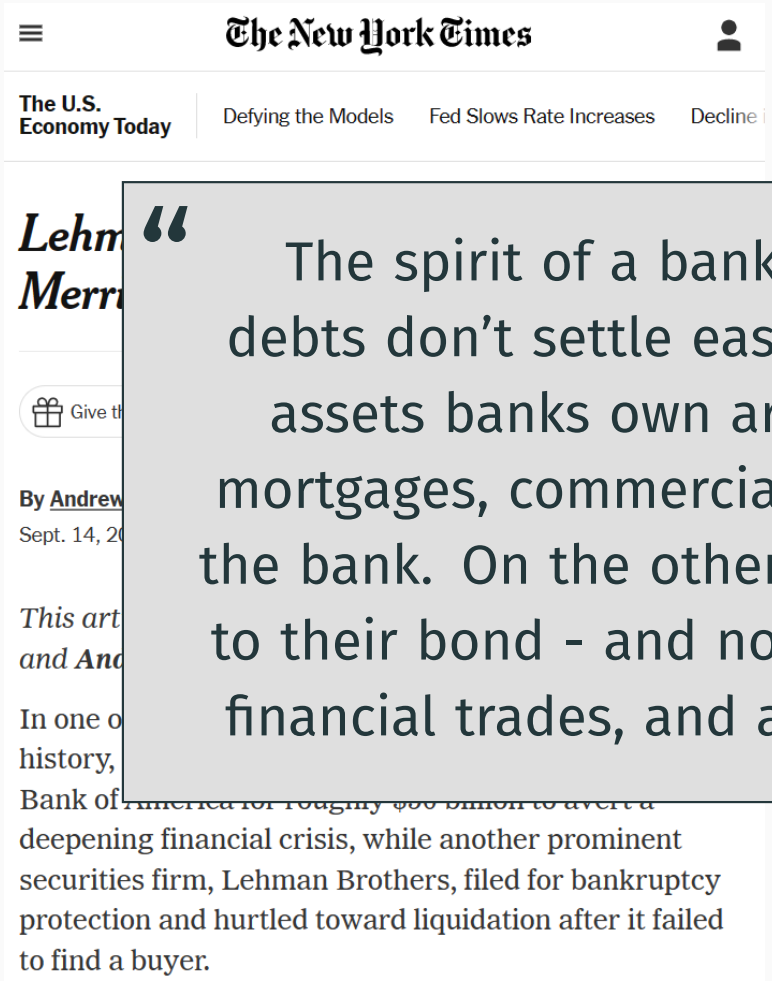
1. John C. Hull. *Options, Futures, and Other Derivatives*. Pretice-Hall
2. Dominic O'Kane. *Modelling Single-name and Multi-name Credit Derivatives*. Wiley, 2008
3. John Gregory. *Counterparty Credit Risk and Credit Value Adjustment*. Wiley, 2010

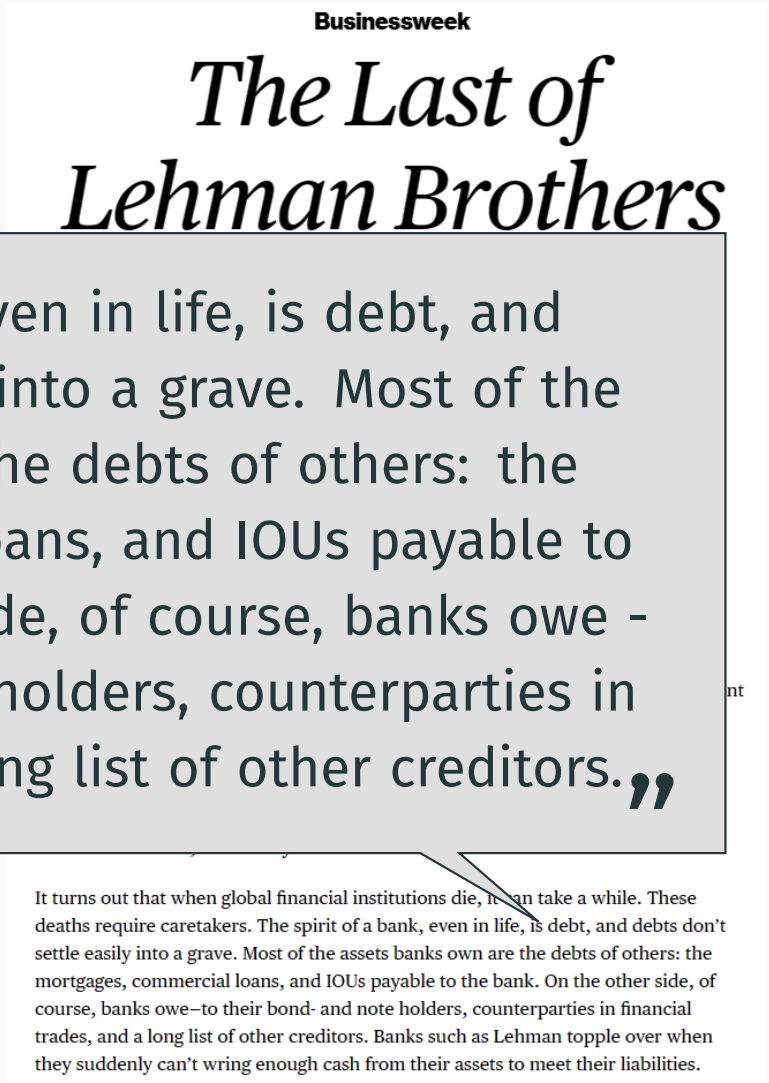
Definition of Credit Risk

Banking as a credit intermediation business



A real story – the fall of Lehman Brothers





> "The spirit of a bank, even in life, is debt, and debts don't settle easily into a grave. Most of the assets banks own are the debts of others: the mortgages, commercial loans, and IOUs payable to the bank. On the other side, of course, banks owe - to their bond - and note holders, counterparties in financial trades, and a long list of other creditors."

Defining default (I)

Definition of default varies with context and could be legalistic.

Example 1 – Moody's definition of default[4]

For Credit Rating

- A missed or delayed disbursement of interest and/or principal, including delayed payments made within a grace period;
- Bankruptcy, administration, legal receivership, or other legal blocks (perhaps by regulators) to the timely payment of interest and/or principal; or
- A distressed exchange occurs where: (i) the issuer offers debt holders a new security or package of securities that amount to a diminished financial obligation (such as preferred or common stock, or debt with a lower coupon or par amount, lower seniority, or longer maturity); or (ii) the exchange had the apparent purpose of helping the borrower avoid default.

Defining default (II)

Example 2 – Basel's definition of default[5]

For Regulatory Capital

A default is considered to have occurred with regard to a particular obligor when either or both of the two following events have taken place.

1. The bank considers that the obligor is unlikely to pay its credit obligations to the banking group in full, without recourse by the bank to actions such as realising security (if held).
2. The obligor is past due more than 90 days on any material credit obligation to the banking group. Overdrafts will be considered as being past due once the customer has breached an advised limit or been advised of a limit smaller than current outstandings.

Defining default (III)

Example 3 – Market definition of credit events

In credit risk derivatives context the definition of default is recorded in product documentation as a Credit Event, typically one of the following

- Bankruptcy or insolvency proceedings
- Failure to Pay
- Obligation default and debt acceleration
- Repudiation / moratorium
- Restructuring
- government intervention

Defining credit risk

- Credit risk is the risk fo losses owing the fact that borrowers or counterparties may be unwilling or unable to fulfill their contractual obligations.
- Broadly speaking, it includes:

Default risk is the risk that a scheduled payment of interest or principal on an asset is not received.

Recovery risk is the risk that following a default, the size of the recovered amount is much less than the amount owed.

Spread risk is the risk that the value of a security falls as the market's view regarding the credit quality of the debtor changes. It is also the "price" to insure against the default of the issuer.

Lending risk

- The most traditional form of credit risk, which originates from the lending of a principal amount from one party to another.
- Typical instruments are commercial loans, mortgages loans, credit card receivables, bonds, etc.
- Characterised by a fixed amount of principal at risk and a unilateral exposure.

Issuer risk

- “Lending risk” embedded in credit derivatives or securitisation products, whose values are exposed to the creditworthiness of the underlying issuer(s).
- Example instruments are bond options, bond forwards, credit default swaps, mortgage-backed securities etc.
- Provides a variety of different exposures to the issuer’s creditworthiness: may be isolated from interest rate risk, may be either long or short, etc.

Counterparty risk (I)

- The risk of not being able to crystalise profits from a portfolio of derivatives because of counterparty default.
- Example instruments are interest rate swaps, swaptions, credit default swaps, or any derivative (or repurchase) transaction for that matter.
- Characterised by uncertain and bilateral exposure. With netting arrangement in place, only meaningful at the portfolio level, which makes it even more complex.
- Could be intertwined with issuer risk in derivative portfolios: right-way risk and wrong-way risk.

Counterparty risk (II)

Right-way risk

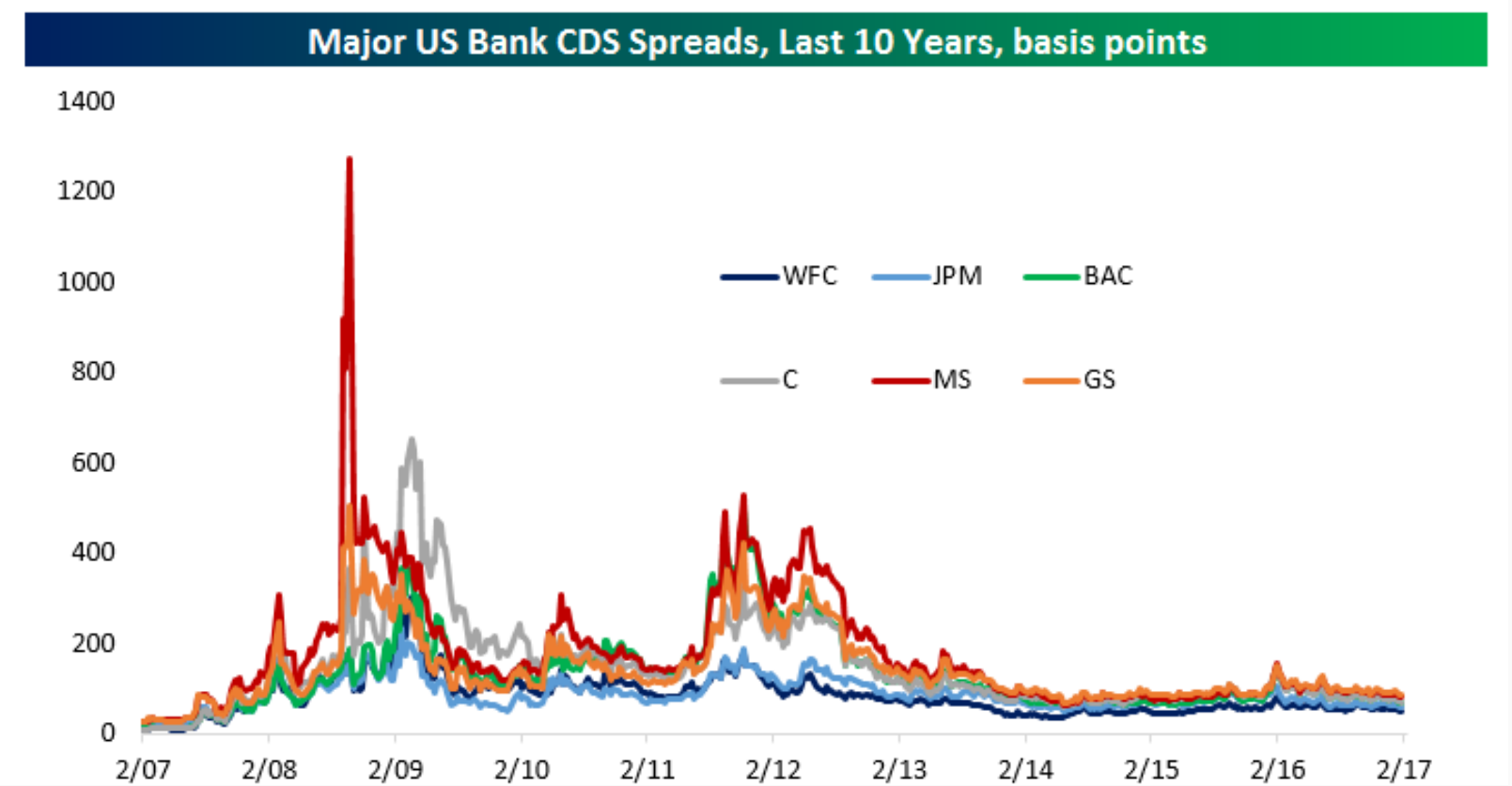
- A situation in which credit exposure to a counterparty decreases as its creditworthiness worsens.
- Example: a gold producer selling gold forward to a bank as a hedge - as gold price falls, the producer is more likely to default but the forward is less in the money for the bank.

Wrong-way risk

- A situation in which credit exposure to a counterparty increases together with the risk of the counterparty's default.
- Example: a bank selling a put option on its own stock - as the stock price falls, the bank is more likely to default and the option is more in the money for the option buyer.

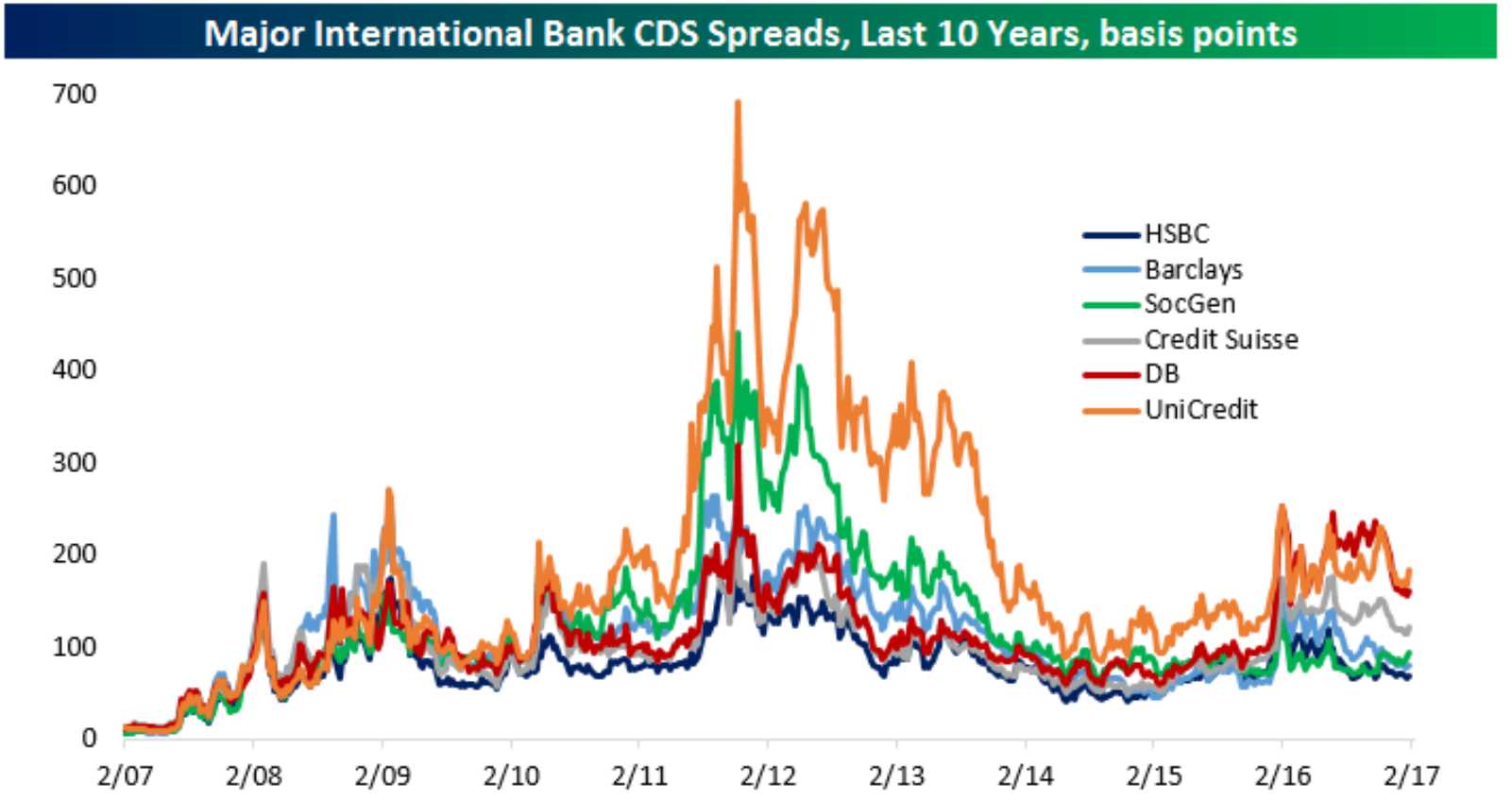
Credit contagion and systemic risk (I)

CDS Spreads for US Banks[6]

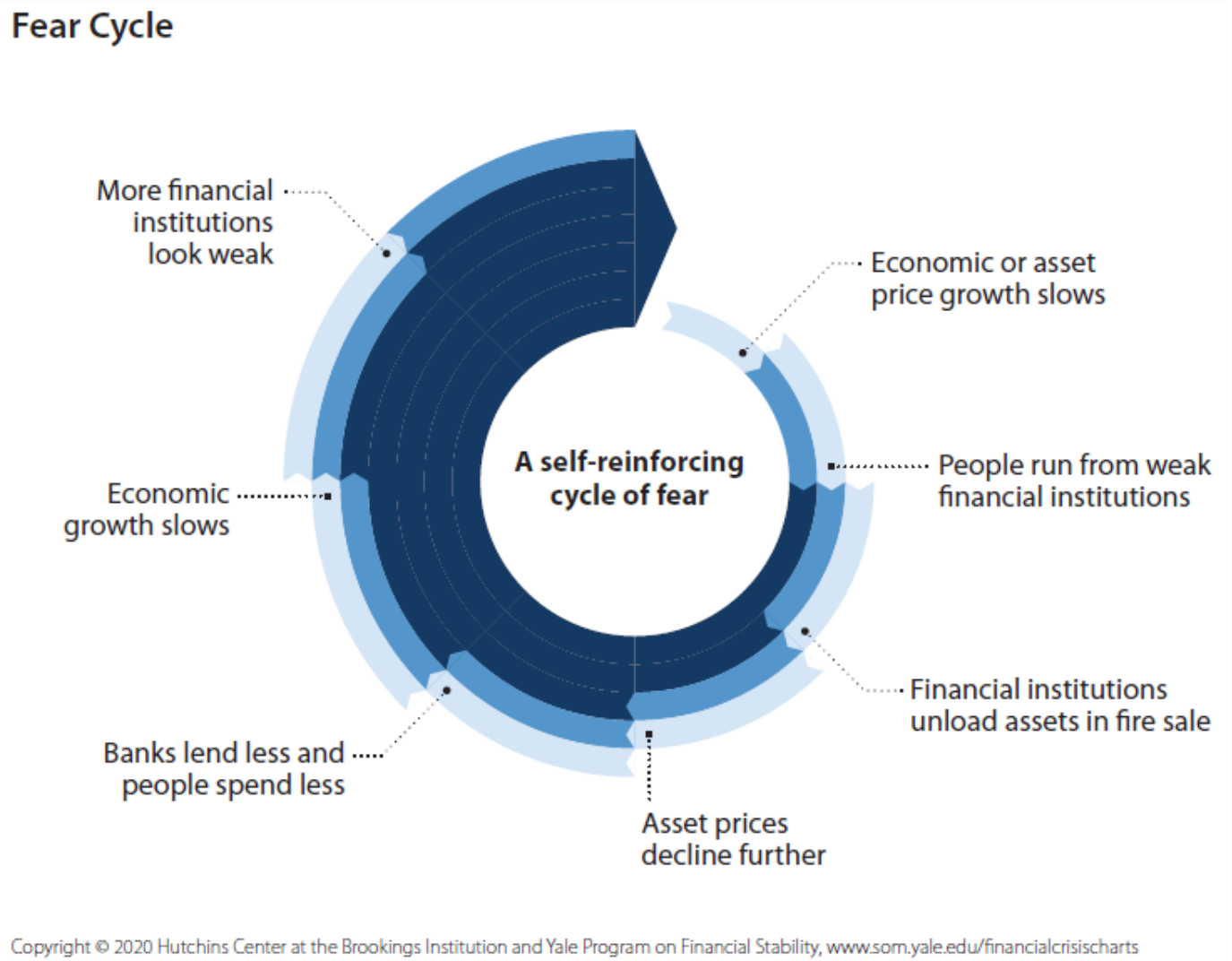


Credit contagion and systemic risk (I)

CDS Spreads for European Banks[6]



Credit contagion and systemic risk (II)



Credit contagion and systemic risk (II)

- Systemic risk is the risk of disruption to the entire financial markets that is caused by the failure of a few market participants.
- The global financial crisis is a perfect example, where the bailout / takeover / bankruptcy of Northern Rock, Bear Stearns, Merrill Lynch, Lehman Brothers, American International Group, and Royal Bank of Scotland are just a few notable events among many more (see a fuller list here).

Traded Credit Products

Overview of traded credit products

Securities

- bonds
- floating rate notes

Repurchase agreement

- repo
- reverse repo

Securitisation

- asset-back securities
- mortgage-back securities

Derivatives

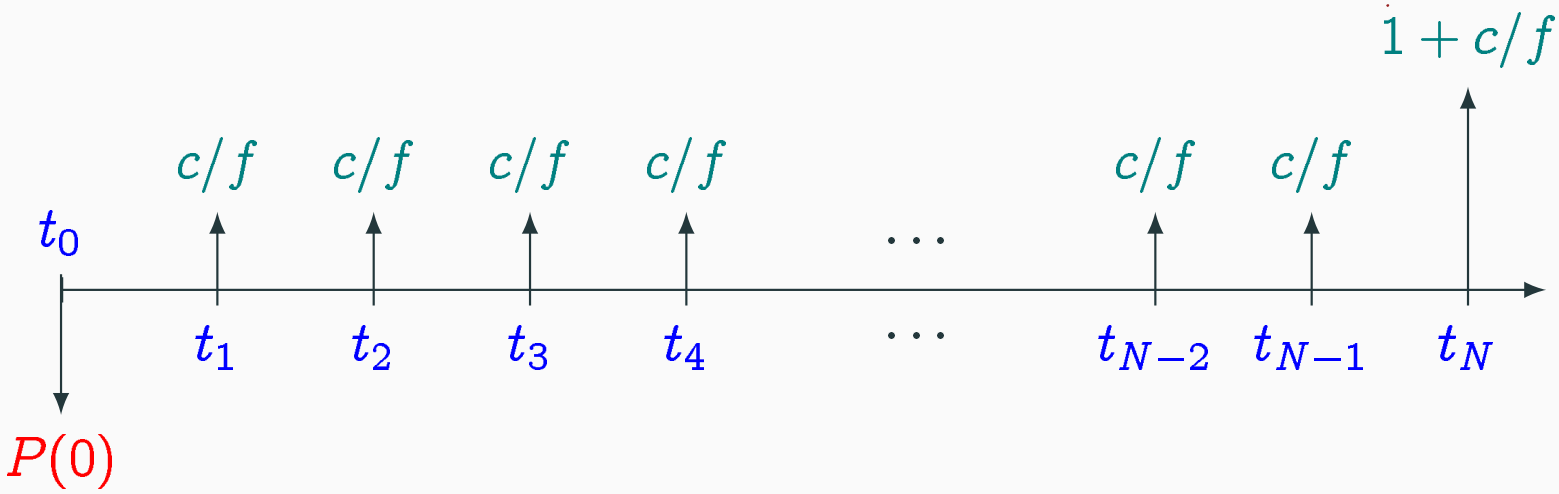
- asset swaps
- total return swaps
- credit default swaps
- n-to-default swaps
- synthetic collateralised debt obligations (CDO)

Bonds

Per Cambridge Dictionary: an official paper given by the government or a company to show that you have lent them money that they will pay back to you at a particular interest rate.

buying bond ⇒ lending risk

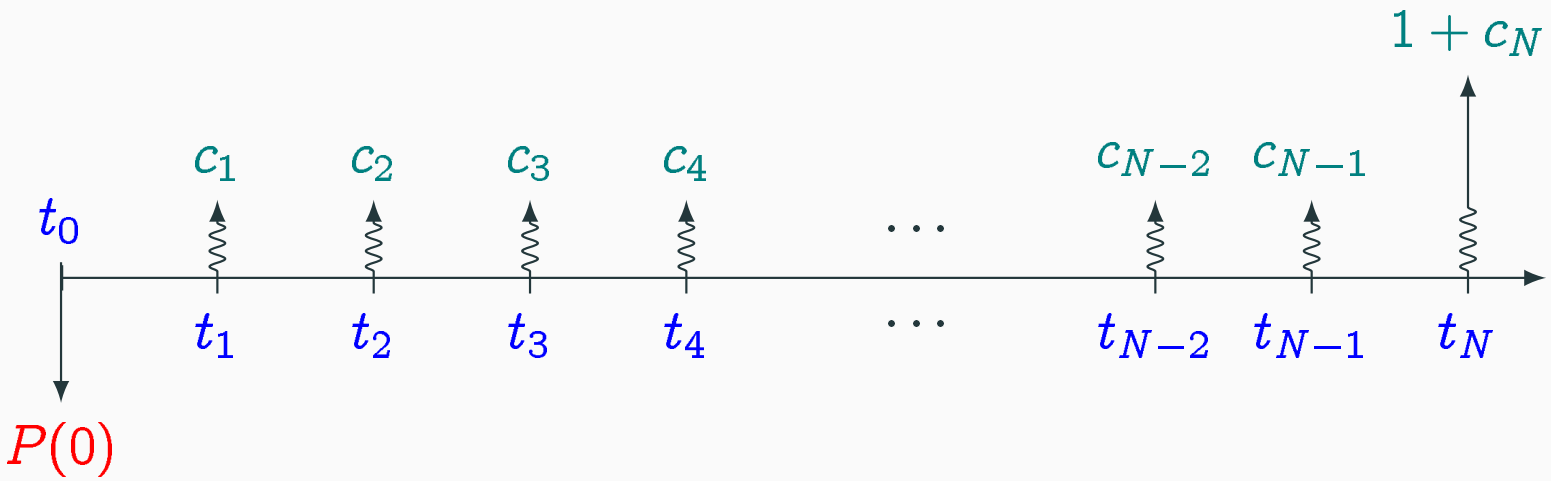
- The issuer could be a government or corporate entity
- Denominated in local or foreign currency (e.g., panda bonds)
- The coupons at a fixed annual coupon rate c may be paid with a frequency f (e.g., $f = 2$ for semi-annual frequency)



Floating rate notes

A floating rate note (FRN) is a bond which pays a coupon linked to some variable interest rate index.

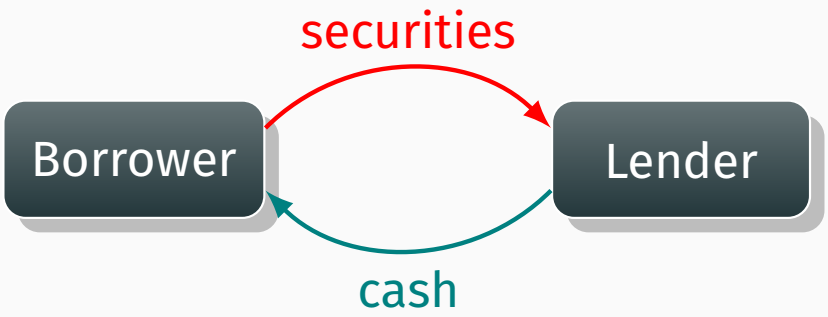
- The rate index R used to be predominantly Libor which is replaced by new benchmark risk-free rates across jurisdictions.
- The investor receives a coupon of a rate index plus an annualised fixed spread $F(0)$, paid with a given frequency and day count convention or $c_n = \Delta\left(t_{n-1}, t_n\right)\left(R\left(t_{n-1}, t_n\right) + F(0)\right)$.



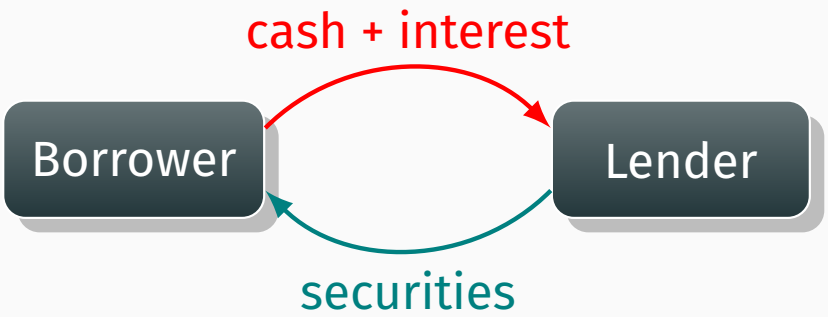
Repurchase agreement

A repurchase agreement (repo) is a form of short-term borrowing, where one party (the borrower) sells a security to another (lender) for cash and buys it back at a later date at a higher price.

- Equivalent to a cash transaction and a forward contract.
- The difference between forward and spot prices is the interest.
- Effectively a collateralised loan.
- A repo for the borrower is a reserve repo for the lender.



At Inception



At Maturity

Credit derivatives

1. Its payoff is contingent on the occurrence of a credit event.
2. It makes it easier to go short credit risk, to hedge or to express a view.
3. It's likely to be unfunded with minimal upfront cost.
4. It's a tool for credit risk transfer.
5. It (used to) offer(s) exposure to credit volatility and credit correlation.

Exchange-traded vs. OTC derivatives

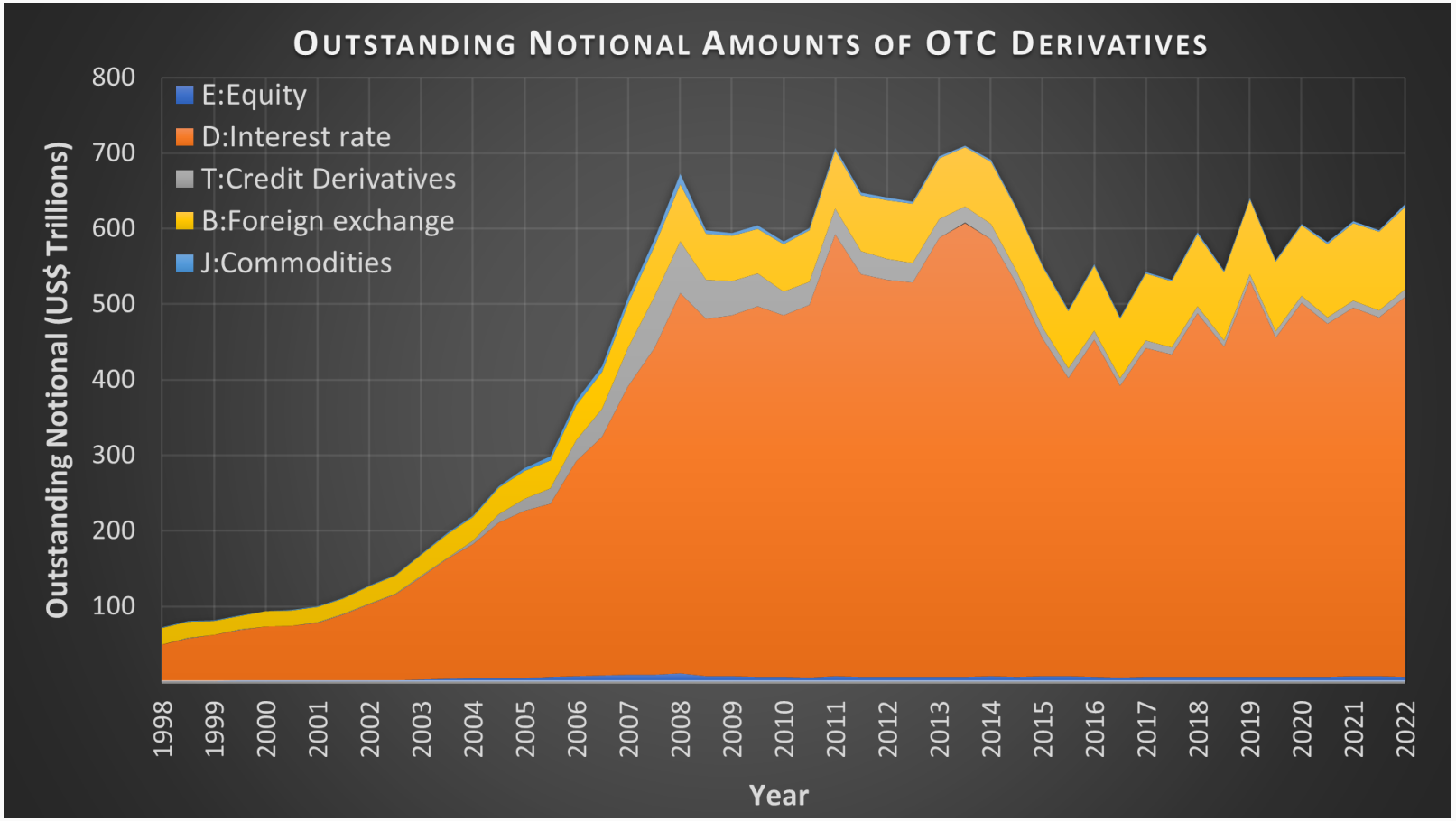
Exchange-traded

- standardised contracts
- high transparency
- CCR exposure to clearing house
- margined per clearing house rules
- limited product offerings

Over-the-counter

- bespoke contracts
- lower transparency
- CCR exposure to bilateral counterparty
- some are cleared through central counterparties
- uncleared OTCDs subject to margin rules

Trend of oustanding notional amount for OTCDs



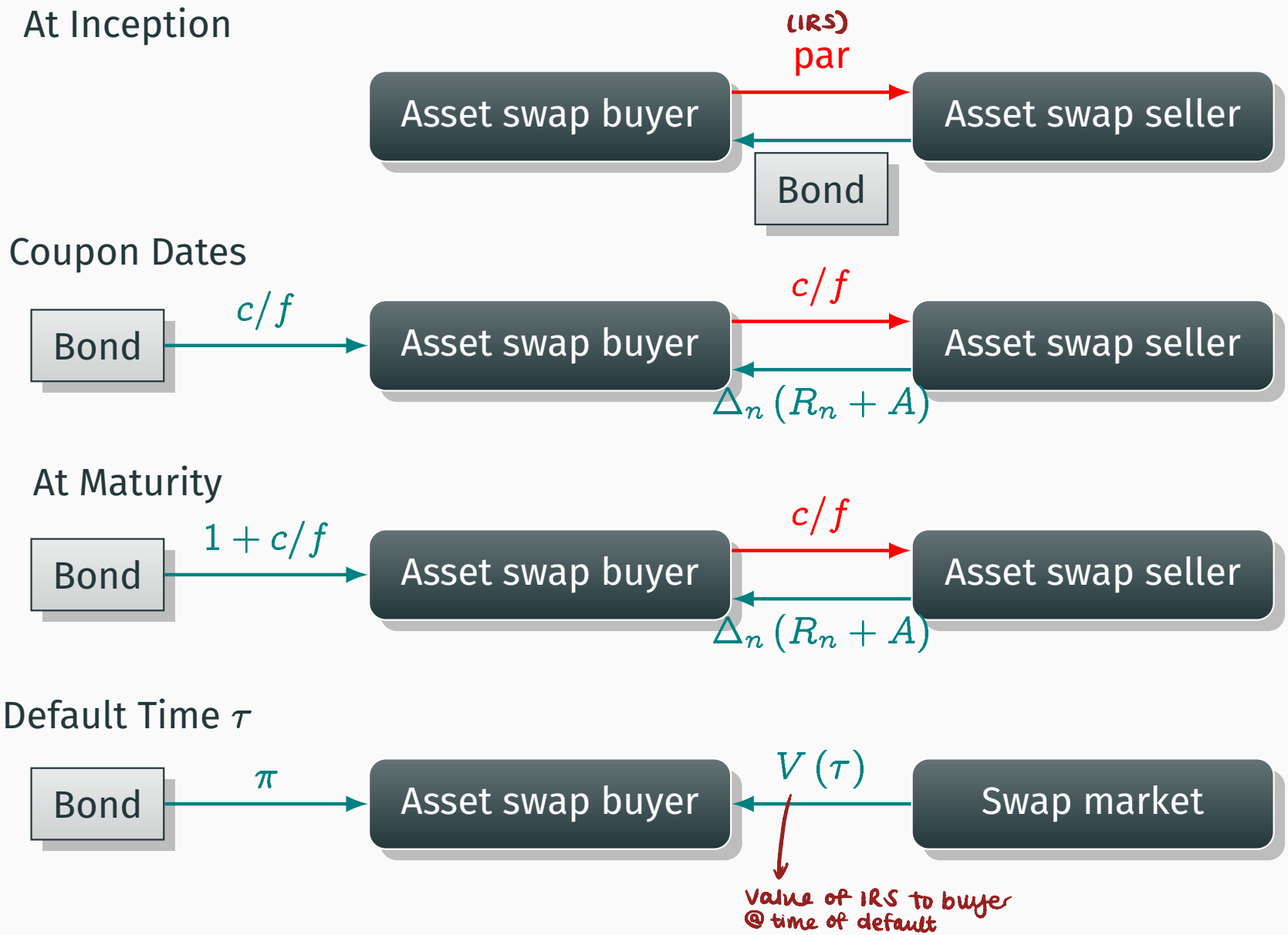
Data source: BIS

Asset swaps

An asset swap is a package consisting of a bond an interest rate swap (IRS) which together cost par at inception.

- A synthetic position in an FRN by combining a fixed rate bond and an IRS.
- The asset swap seller delivers to the buyer a fixed rate bond with price P in return for a payment of par.
- The asset swap buyer enters into a payer IRS, where the fixed leg is identical to the bond. On the floating leg, the buyer receives a floating rate index R plus the asset swap spread A. The asset swap spread is a measure of credit quality of the bond.
- Upon bond default, the asset swap buyer could sell the bond for its recovery π. However, the IRS stays and may be unwound at market value V.

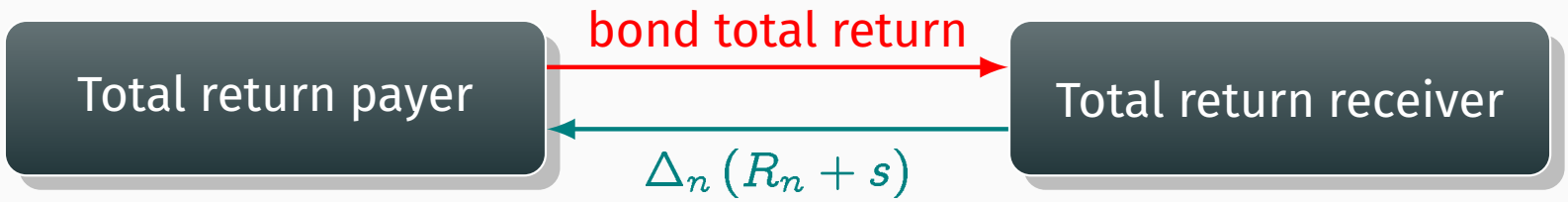
Asset swaps


At Inception
(IRS)
par
Asset swap buyer
Asset swap seller
Bond
Coupon Dates
Bond
c/f
Asset swap buyer
c/f
Asset swap seller
$\Delta_n (R_n + A)$
At Maturity
Bond
$1 + c/f$
Asset swap buyer
c/f
Asset swap seller
$\Delta_n (R_n + A)$
Default Time τ
Bond
π
Asset swap buyer
$V(\tau)$
Swap market
Value of IRS to buyer
@ time of default

Total return swaps

A total return swap (TRS) involves swapping interest payments based on a specified fixed or floating interest rate in return for receiving the total return on a bond (or any asset or index).

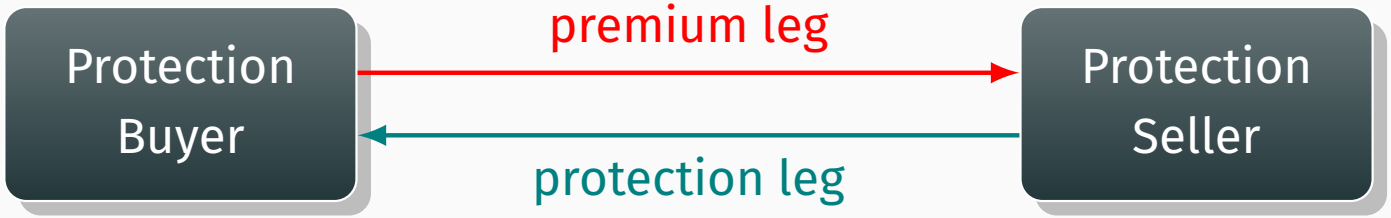
- A synthetic position in a bond, which could be long or short.
- Unfunded, i.e., the initial cost is minimal.
- The total return leg includes capital gain / loss as well as any interest payments. The interest rate leg pays a floating rate index R plus a spread s.
- The TRS terminates when the bond defaults.



Credit default swaps

A credit default swap (CDS) protects the protection buyer, from the loss from par on a specified face value of bonds or loans following the default of their issuer, or the reference entity, until its maturity.

- A synthetic position in the credit risk of the reference entity, which is long for the protection seller and short for the protection buyer.
- The protection leg is effectively an insurance payout upon default of the reference entity.
- Unfunded, i.e., the initial cost is low, with running premium paid regularly by the protection buyer in the premium leg.



nth-to-default basket

A default basket is almost identical to a CDS. The credit event in this case is the nth default in a basket of N credits.

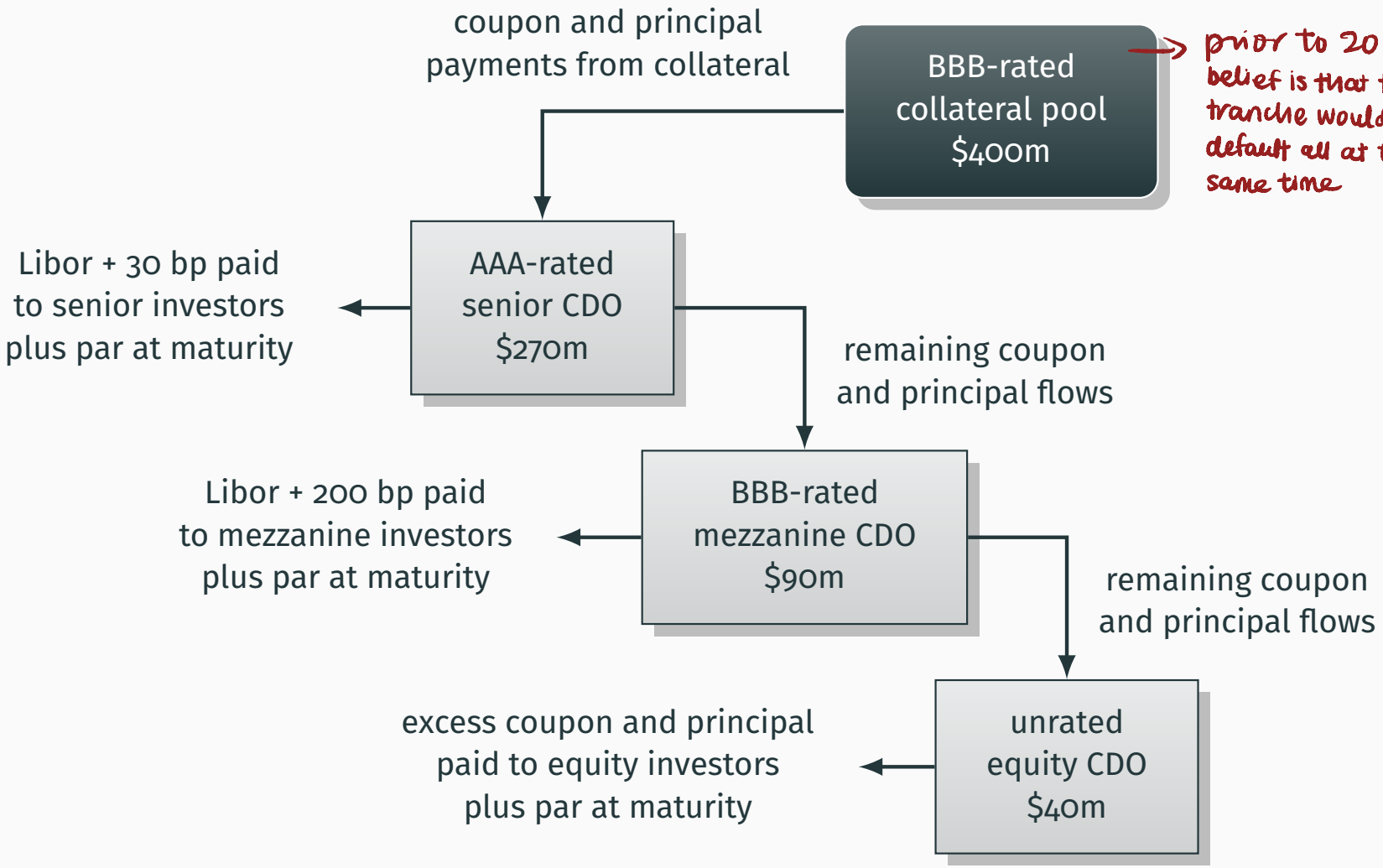
- It provides exposure to credit correlation in addition to credit risk of basket constituents.
- The lower n is, the more expensive the protection is, e.g., 2nd-to-default is cheaper than 1st-to-default. Any intuition?
- The protection seller of a first-to-default takes a long position in credit correlation. Any intuition?

Collateralised debt obligation

A collateralised debt obligation (CDO) transforms credit risk of a pool of assets into securities with different credit risk profiles.

- It provides exposure to credit correlation in addition to credit risk of assets in the underlying pool.
- Cashflow CDOs are sold in a funded format, where the sale proceeds fund the purchase of the underlying pool.
- All coupons and principal payments follow a waterfall structure when being distributed to different tranches.
- A synthetic single tranche CDO (STCDO) is unfunded and bespoke with underlying pool being a basket of CDSes.
- The underlying pool of STCDO is typically much larger than that of a nth-to-default basket.

Collateralised debt obligation



Reproduced from O'kane[2]

Credit Risk Mitigants

Credit risk mitigants

Financial institutions (FIs) employ credit risk mitigation techniques such as

1. Credit Risk transfer
2. Collaterals and guarantees
3. Hedging
4. Netting and Margining
5. Central clearing

Credit risk transfer

- Bank guarantees and credit insurances are traditional examples of credit risk transfer arrangements.
- Trading, hedging and securitisation are newer forms of credit risk transfer.
- Risk may be transferred out of the banking system to investors with varying levels of sophistication and risk appetite, e.g., cash CDOs sold to retail investors.
- It may reduce the incentive to perform credit due diligence and ongoing monitoring.

Collaterals and guarantees

Collaterals and guarantees are widely used to mitigate credit risk.

- In the small- and medium-sized enterprises sector, guarantees tend to be personal (e.g., by the business owner) in nature and collaterals are typically illiquid.
- When dealing with FIs and large corporates, third-part guarantees are more often and collaterals may be in the form of marketable financial instruments.

Hedging

- FIs may hedge their credit risk exposures in the market, e.g., using CDS contracts.
- This is effectively a transformation from issuer risk to counterparty credit risk.
- The ability to hedge depends on market liquidity and therefore cost of protection.

Netting and margining

- Widely used for bilateral OTCD transactions, in part thanks to the post-GFC regulatory reform.
- Netting is the aggregation and hence offsetting of transactions with the same counterparty. It allows counterparties to reduce exposure to each other in case of default by either.
- Margining: exchanges of variation margins to cover current exposure and initial margins to cover potential future exposure during the margin period of risk.
- Between B and C, there is a portfolio of six trades, with current MtM of 3, -3, 8, 2, -10, and -4 from B's perspective.
  - What are the counterparties' current exposure to each other?
  - What's the balance of variation margin between them?

C exposed to B by 4.

Variation margin changes daily

Central clearing

- Increasingly being used for simple derviatives, in part thanks to the post-GFC regulatory reform.
- A central counterparty (CCP) stands as an entity to intermediate a set of standard contracts. It does not take on any market risk by entering offsetting trades with different clearing members.
- Effectively a transfer of counterparty credit risk from a bilateral counterparty to the CCP.
- Netting and margining.
- Default fund contribution and CCP's skin in the game.

Historical vs. Market

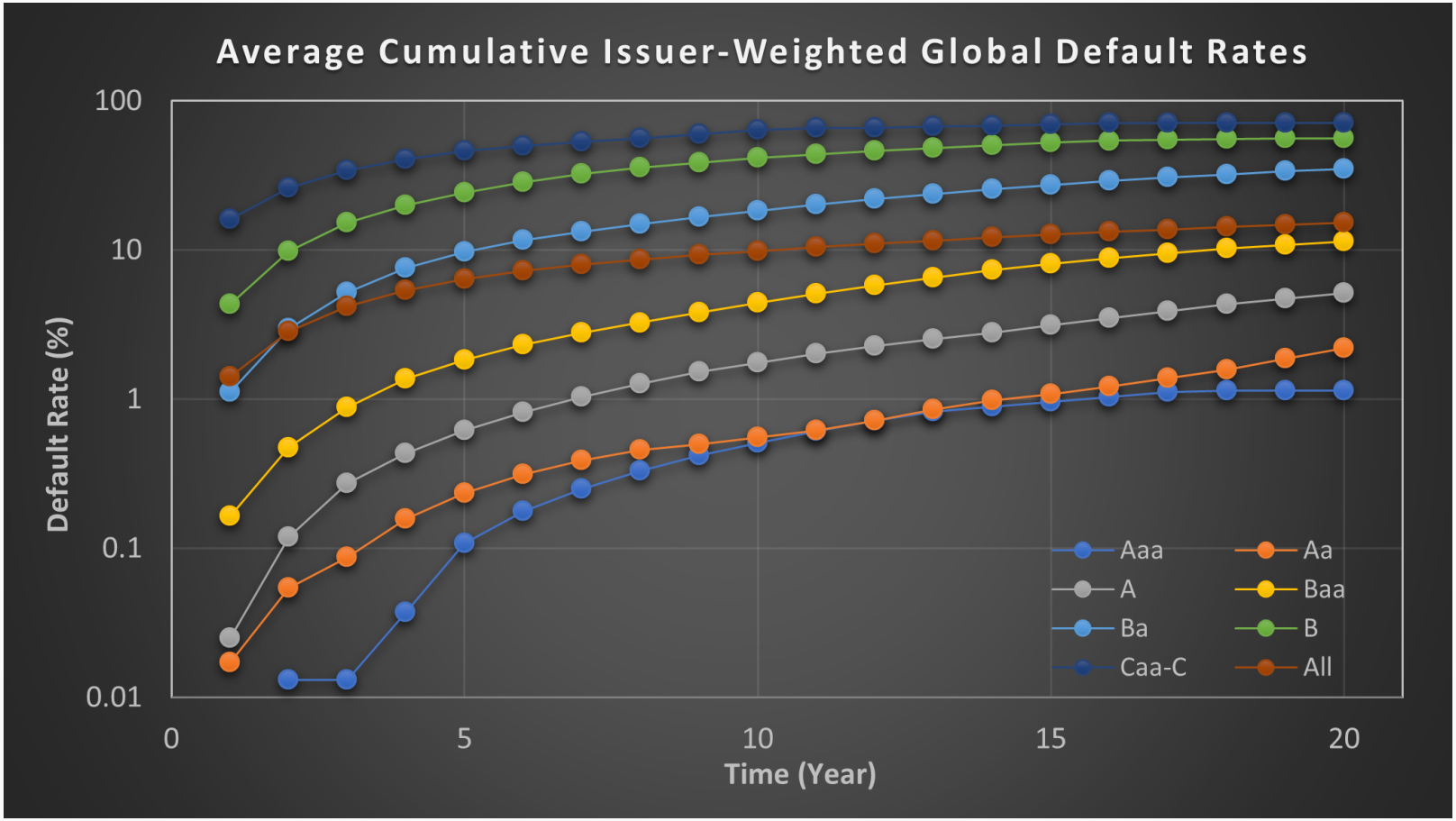
Probability of default

Cumulative default rates (%) for B-rated issuers[7]

Term (year)	1	2	3	4	5	7
Default rates	4.333	9.752	15.106	19.864	24.175	32.164

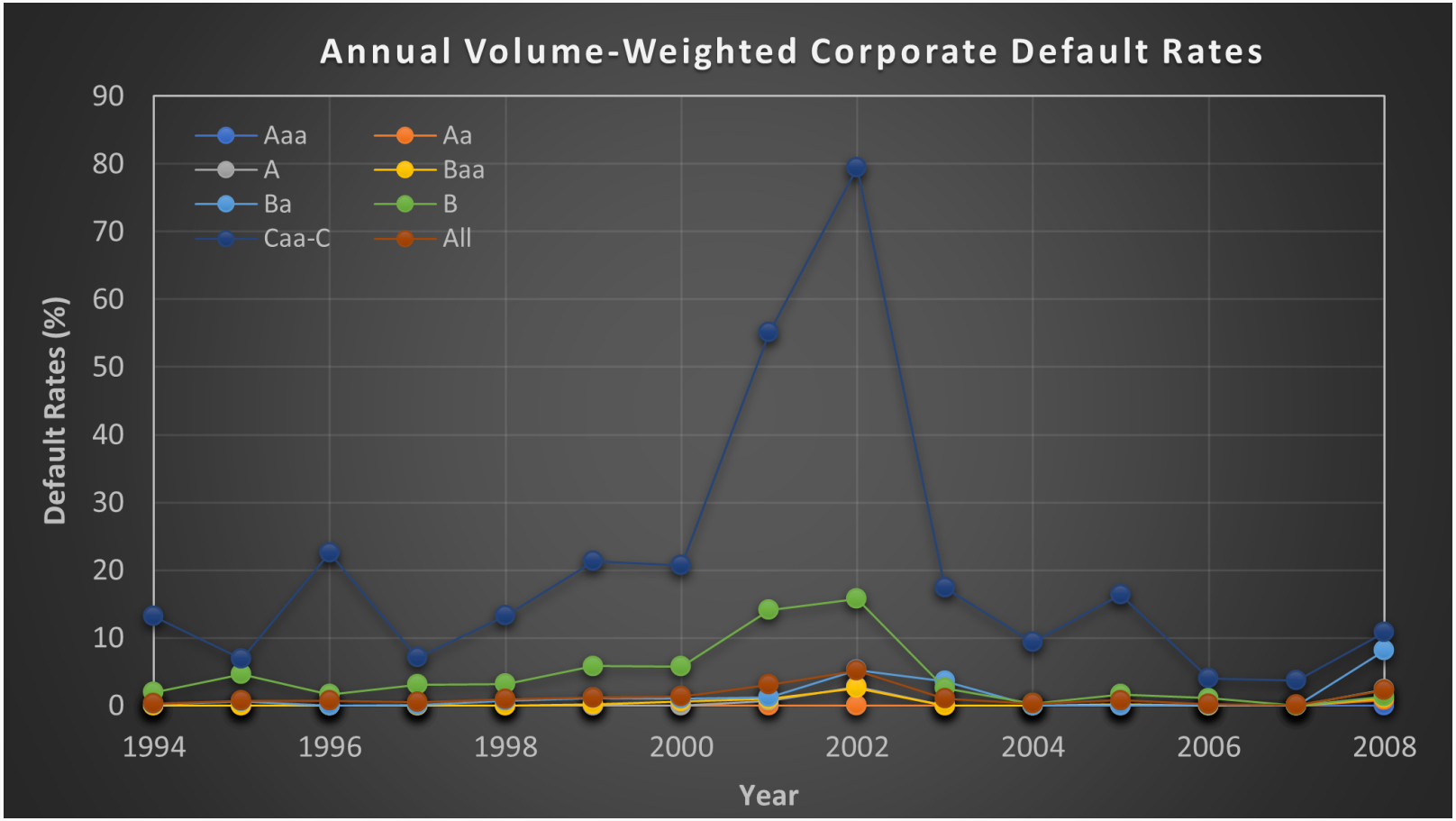
- Unconditional 1Y default probability $Pr(\tau \leq 1) = 4.333\%$
- Unconditional 1Y survival probability
  $Pr(\tau > 1) = 1$ [redacted] 7%
- Unconditional default probability in the 2nd year
  $Pr(1 < \tau \leq 2) = Pr(\tau \leq 2) - Pr(\tau \leq 1) = 5.419\%$
- Conditional default probability in the 2nd year
  $$Pr\left(\tau \leq 2 \,|\, \tau > 1\right) = \frac{Pr(\tau \leq 2) - Pr(\tau \leq 1)}{Pr(\tau > 1)} = 5.664\%$$
- Default intensity $\lambda(t) = \lim_{dt \to 0} \frac{Pr\left(\tau \leq t + dt \,|\, \tau > t\right)}{dt}$

Cumulative default rates by letter rating



Data sourced from Moody's[7]

Annual default rates by letter rating



Data sourced from Moody's[7]

Recovery rate

- Recovery rate is a source of uncertainty upon default.
- Rating agencies measure recovery rate as the price of a defaulted asset within a given period (say 30 days).
- Recovery rate is driven by the seniority of the debt in the issuer's capital structure, i.e., more values could be recovered from a senior debt than from a subordinated debt.
- The distribution of historically observed recovery rate is broad.
- Recovery rates are significantly negatively correlated with default rates.

Average corporate debt recovery rates (1982-2008)

Data sourced from Moody's[7]

Bond Seniority	Issuer-Weighted	Value-Weighted
Sr. Secured	52.3%	53.0%
Sr. Unsecured	36.4%	32.4%
Sr. Subordinated	31.7%	26.4%
Subordinated	31.0%	23.5%
Jr. Subordinated	24.0%	16.8%

- Recovery rate is driven by the seniority of the debt.
- Lower values were recovered from larger issuers upon default, as value-weighted recovery rates are lower than issuer-weighted recovery rates.

Recovery rates of FIs defaulted in 2008

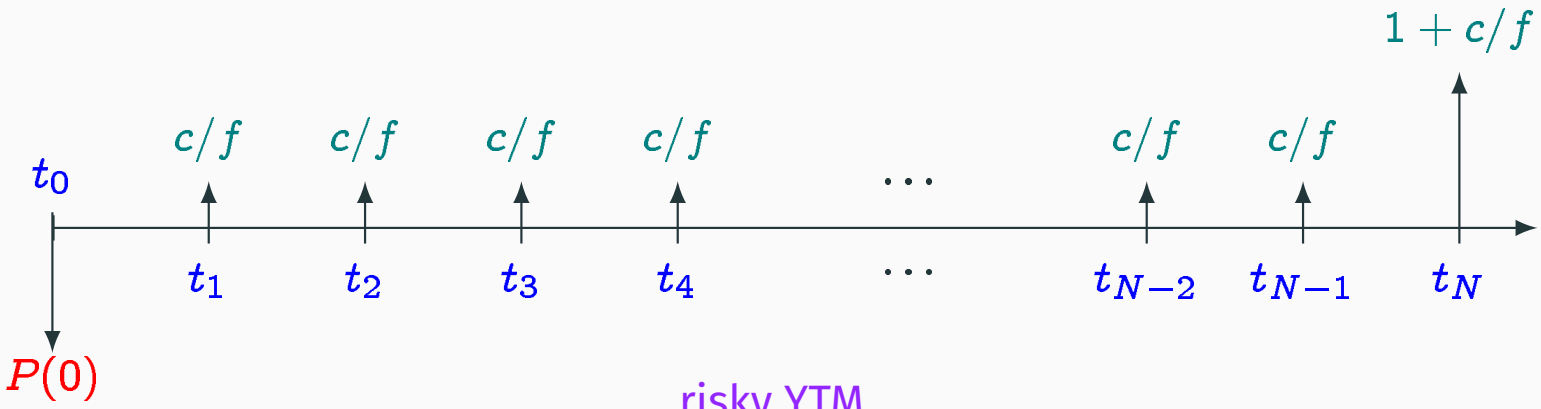
Data sourced from Moody's[7]

Company	Domain	Default Volume ($m)	Sr. Unsecured Bond Recovery
Lehman Brothers Holdings, Inc.	United States	120,164	9.30%
Kaupthing Bank hf	Iceland	20,063	4.00%
Glitnir banki hf	Iceland	18,773	3.00%
GMAC LLC	United States	17,190	69.90%
Washington Mutual Bank	United States	13,600	26.50%
Residential Capital, LLC	United States	12,315	51.70%
Landsbanki Islands hf	Iceland	12,161	3.00%
Washington Mutual, Inc.	United States	5,746	57.00%
GMAC of Canada Ltd	Canada	265	70.70%
Downey Financial Corp.	United States	200	0.50%
Fremont General Corporation	United States	166	46.00%
Luminent Mortgage Capital, Inc.	United States	131	27.30%
Triad Financial Corporation	United States	89	76.50%
Franklin Bank Corp.	United States	80	0.00%
GMAC International Finance B.V.	Netherlands	51	85.50%

Market-implied probability of default

- Market prices of traded instruments contain information on issuers' default rates.
- Given a modelling framework, default probability (or intensity) may be extracted from these instruments, such as risky bonds.
- The difference in prices of a risk-free bond and a risky bond is driven by how likely the issuer is to default.

Yield spread



risky YTM

$$P(0) = \sum_{n=1}^{N} \frac{c/f}{\left(1 + y/f\right)^n} + \frac{1}{\left(1 + y/f\right)^N}$$

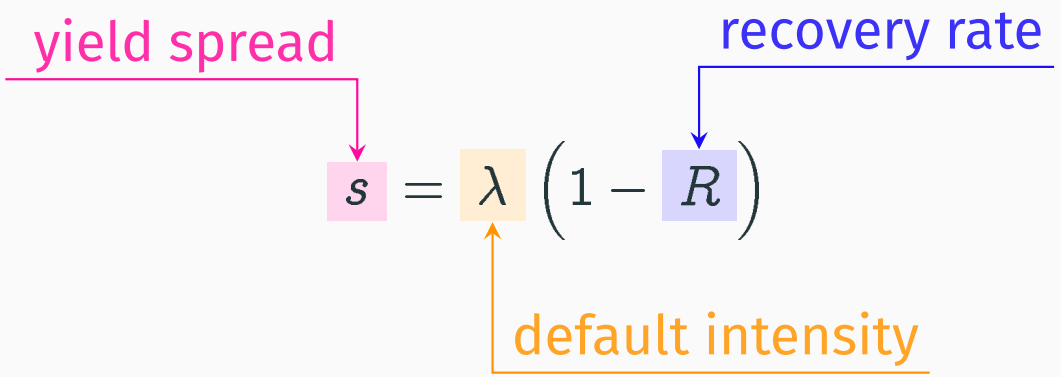
decomposing risky yield into risk free yield

$$= \sum_{n=1}^{N} \frac{c/f}{\left(1 + (y_T + s)/f\right)^n} + \frac{1}{\left(1 + (y_T + s)/f\right)^N}$$

risk-free YTM

yield spread

The credit triangle



- The credit triangle is a useful approximation, which we will revisit later.
- With the yield spread observed in the market and a recovery rate, default intensity may be extracted.
- With default intensity implied from the market, risk-neutral default probability could be derived.

Historical vs. risk-neutral probability of default

- Risk-neutral default probability is almost always much higher than the historical one.
- The market charges a risk premium over the historically observed default rate.
- Default risk premium: to compensate that historical statistics do not reliably predict the future.
- Volatility risk premium: to compensate that the credit quality of an issuer may change.
- Liquidity risk premium: to compensate that a reduction in liquidity may prevent the debt being sold.

References

[1] John C. Hull. *Options, Futures, and Other Derivatives*. Pretice-Hall.

[2] Dominic O'Kane. *Modelling Single-name and Multi-name Credit Derivatives*. Wiley, 2008.

[3] John Gregory. *Counterparty Credit Risk and Credit Value Adjustment*. Wiley, 2010.

[4] Moody's. *Moody's Corporate Default Risk Service – FAQ*. URL: https://www.moodys.com/sites/products/ProductAttachments/FAQs%20Default%20Risk%20Service.pdf (visited on 2022).

[5] BCBS. *CRE 36.69 of Basel Framework*. URL: https://www.bis.org/basel_framework/chapter/CRE/36.htm?inforce=20191215&published=20191215 (visited on 2022).

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[6] Bespoke. *A Look At Bank and Broker Credit Default Swap (CDS) Prices*. URL: https://www.bespokepremium.com/think-big-blog/a-look-at-bank-cds/ (visited on 2022).

[7] Moody's. *Corporate Default and Recovery Rates, 1920-2008*. 2009. URL: https://www.moodys.com/uploadpage/MiscAnon/default_and_recovery_rates_02_09.pdf (visited on 2022).