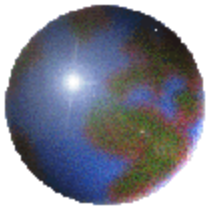


# *Credit Risk*

# *Default is an option*

- Sovereign defaults:
  - Russia 1998
  - Argentina 2002 (93bn USD), again in 2020!
  - Venezuela 2017 (65m USD)
- 2021 sovereign defaults: Belize, Suriname
- 2022 sovereign defaults: Russia, Belarus, Ukraine, Sri Lanka, Ghana.
- 2023: Argentina, El Salvador, Ethiopia, Sri Lanka, Cameroon and Mozambique.

# *First sovereign default*

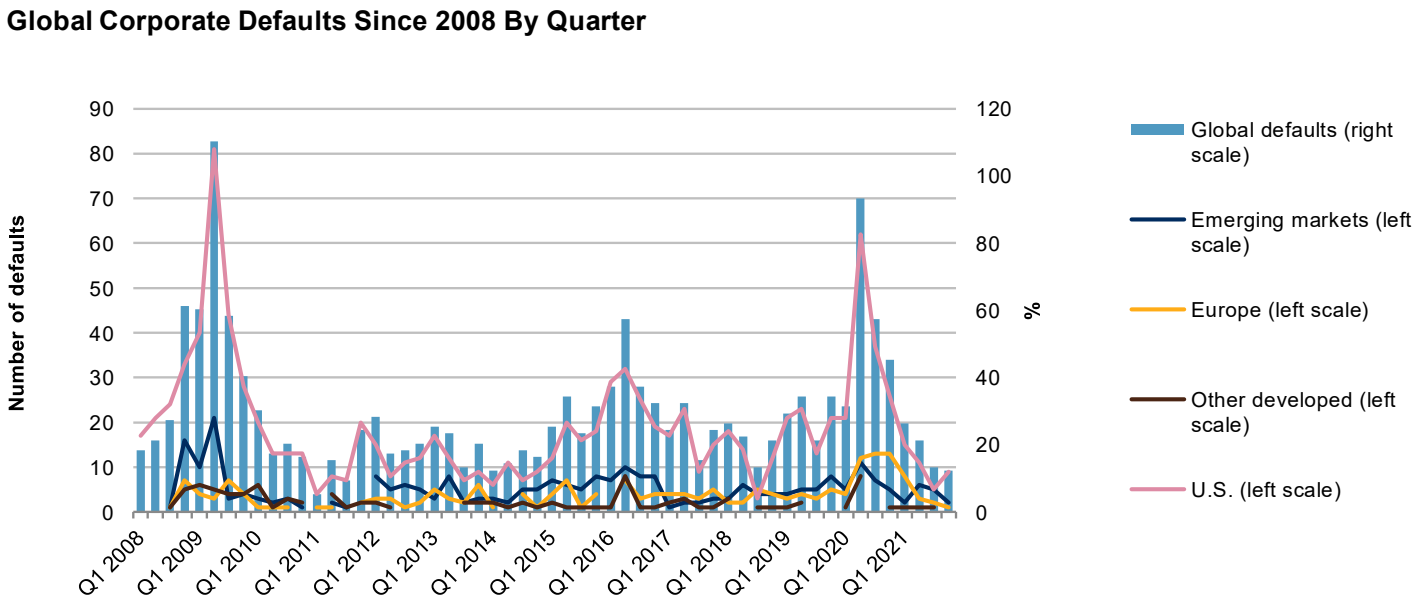
**377 BC**: The temple of Delos loans funds to 12 Greek city states to finance a military campaign.

They were unable to repay the debt, and the temple was forced to take a 80% cut on the principal.

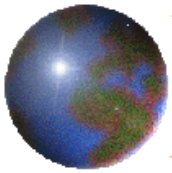
# *Corporate and municipal defaults*

- Corporate defaults
  - Enron 2001 (79 bn USD)
  - Lehman 2008 (600bn USD)
  - General Motors 2009 (84 bn USD)
- Municipal defaults
  - Jefferson County AL (Nov 2011)

# Corporate defaults in time




*Data as of Jan. 5, 2022. Source: S&P Global Ratings Research.



# *Outline of lecture*

- Credit ratings and empirical data on default probabilities
- Implying default probabilities from bond yields
- Credit Default Swaps (CDS) – simplest credit linked derivative
- Pricing CDS and implying default probabilities from CDS spreads

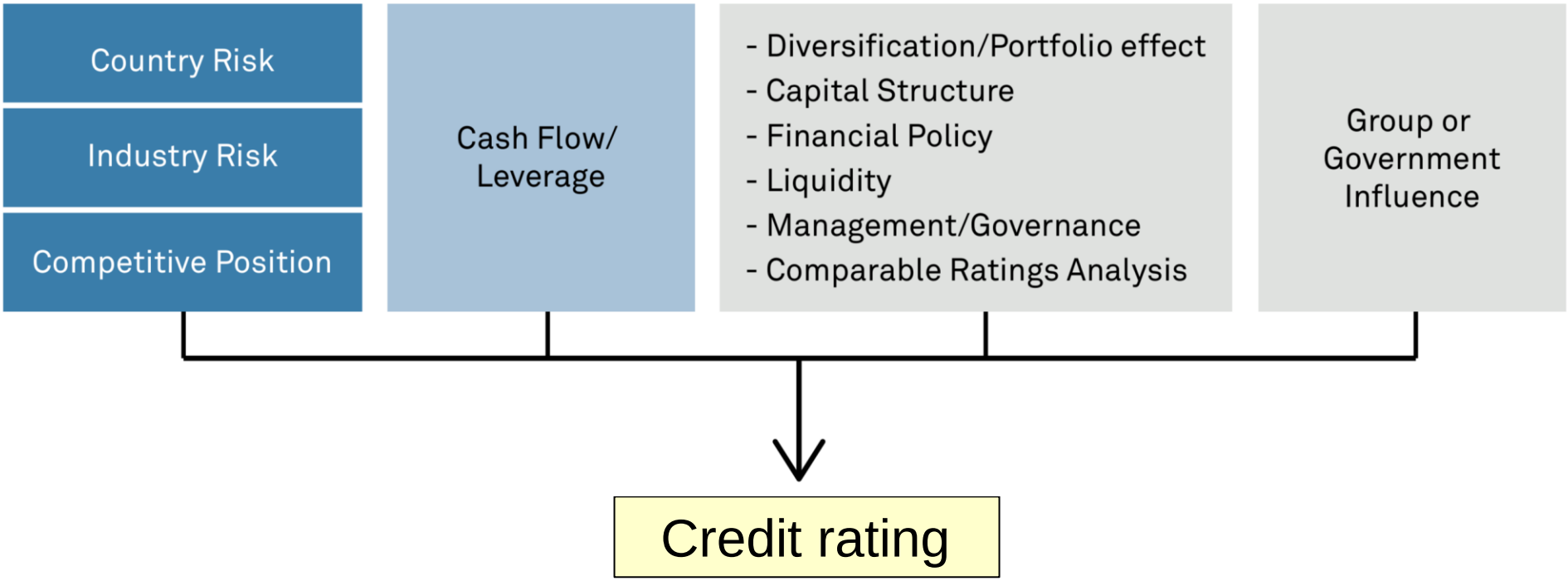
# *Credit Ratings*

- Rating agencies monitor the financial health of companies, and assign them a credit rating
- The credit rating of a company is a relative measure of their credit worthiness compared to other companies
- Most important rating agencies:
  - Standard and Poor's (S&P)
  - Moody's
  - Fitch

# *Credit Ratings*

- In the S&P rating system, AAA is the best rating. After that comes AA, A, BBB, BB, B, CCC, CC, and C
- The corresponding Moody's ratings are Aaa, Aa, A, Baa, Ba, B,Caa, Ca, and C
- Bonds with ratings of BBB (or Baa) and above are considered to be "investment grade"

# *S&P methodology for assessing corporate credit ratings*




Source: https://www.spglobal.com/rating

# *Estimating Default Probabilities*

- Several possible approaches:
  - Use historical data (given an initial credit rating, what is the probability of default after *n* years?)
  - Use bond yields
  - Use credit spreads, available in the CDS market
  - **Structural credit models** which simulate the assets and liabilities of the company (Merton model, Cox model) – will not be discussed in this course

# *Historical Data*

Historical data provided by rating agencies can be used to estimate the probability of default

# *Cumulative Ave Default Rates (%)*

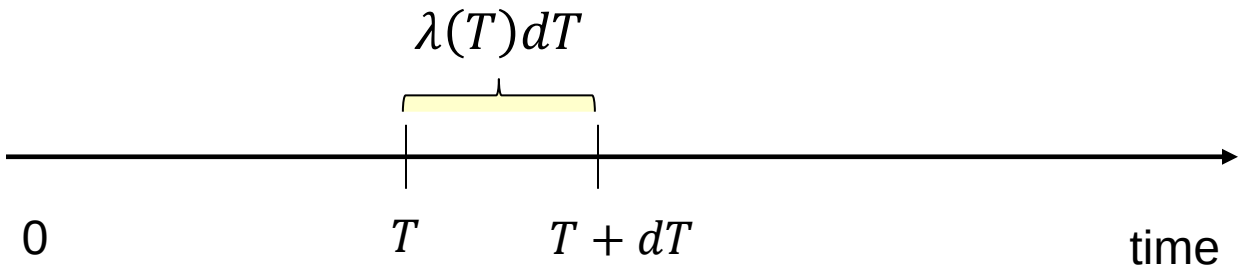
***(1970-2015, Moody's, Table 24.1, page 544)***

| | 1Y | 2Y | 3Y | 4Y | 5Y | 7Y | 10Y |
|---|---|---|---|---|---|---|---|
| Aaa | 0.000 | 0.011 | 0.011 | 0.031 | 0.087 | 0.198 | 0.396 |
| Aa | 0.022 | 0.061 | 0.112 | 0.196 | 0.305 | 0.540 | 0.807 |
| A | 0.056 | 0.170 | 0.357 | 0.555 | 0.794 | 1.345 | 2.313 |
| Baa | 0.185 | 0.480 | 0.831 | 1.252 | 1.668 | 2.525 | 4.033 |
| Ba | 0.959 | 2.587 | 4.501 | 6.538 | 8.442 | 11.788 | 16.455 |
| Caa-C | 10.671 | 18.857 | 25.639 | 31.075 | 35.638 | 41.812 | 47.843 |

# *Interpretation*

- The table shows the probability of default for companies starting with a particular credit rating
- A company with an initial credit rating of Baa has a probability of 0.185% of defaulting by the end of the first year, 0.480% by the end of the second year, and so on

# *Hazard rate*




The hazard rate (also called default density), $\lambda(t)$, at time $t$ is defined so that $\lambda(t)\Delta t$ is the default probability for a short period between $t$ and $t+\Delta t$ , conditional on no default at $T$

# *Survival Probability*

- Denote $V(t)$ the probability of a company surviving to time $t$ (survival probability)
- This satisfies the equation

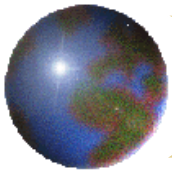
$$V(t+\Delta t) - V(t) = -\lambda(t)V(t)\Delta t$$

This leads to

$$V(t) = e^{-\int_0^t \lambda(t)dt}$$

The cumulative probability of default by time $t$ is

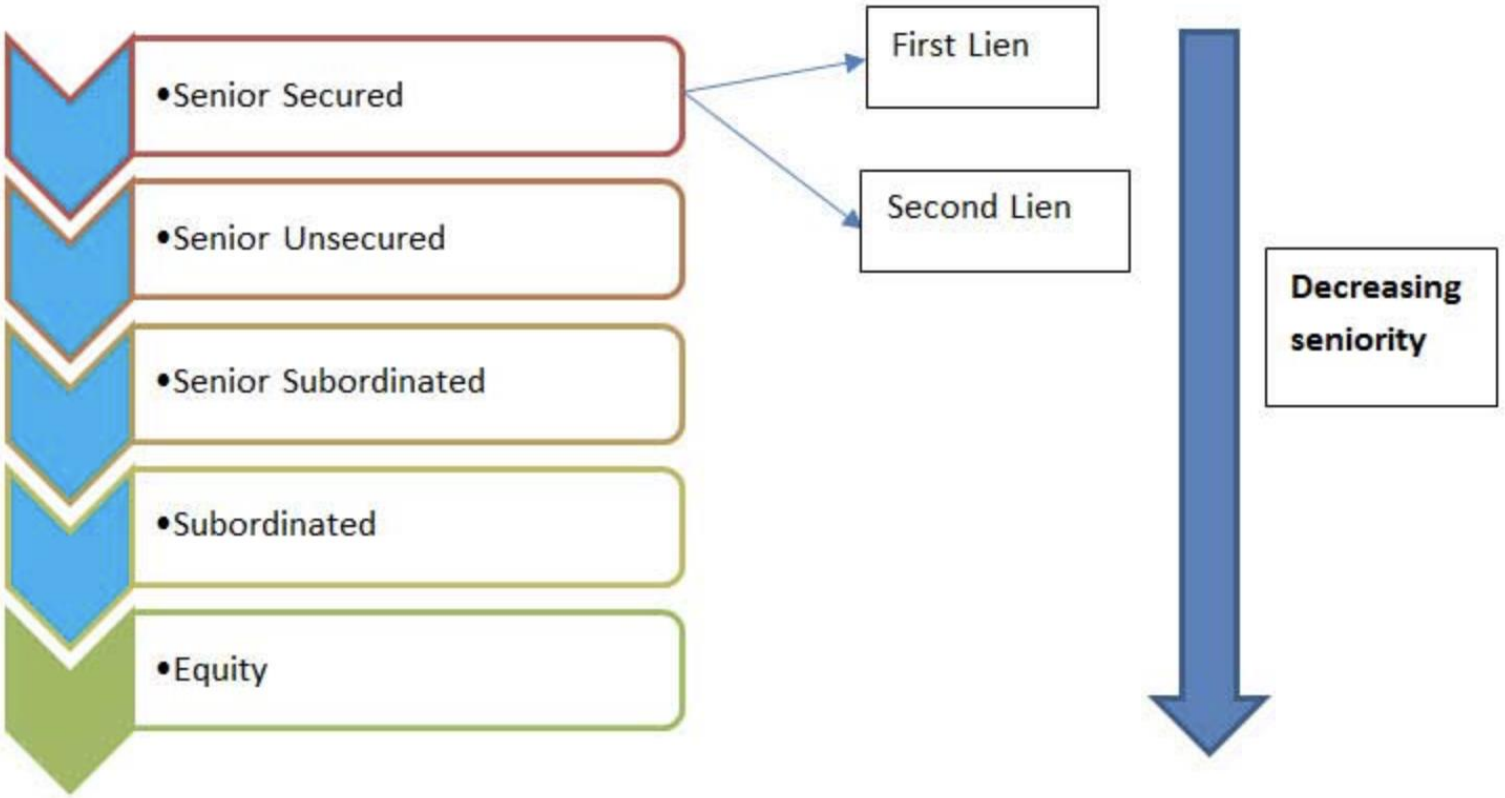
$$Q(t) = 1 - e^{-\bar{\lambda}(t)t}$$



# *Recovery Rate*

- The recovery rate for a bond is usually defined as the price of the bond immediately after default as a percent of its face value
- In the event of default, debt is repaid in decreasing order of seniority.

# *Debt subordination*



# *Recovery Rates; Moody's: 1982 to 2015*

| Class | Recovery (%) |
|---|---|
| First Lien Bond | 53.4 |
| Second Lien Bond | 49.7 |
| Senior Unsecured | 37.6 |
| Senior Subordinated | 31.1 |
| Subordinated | 31.9 |
| Junior Subordinated | 24.2 |

# *Implying hazard rates from market data*

Alternative, forward looking, methods of estimating default probabilities:

- Using bond yield and bond prices
- Using credit spreads implied from Credit Default Swaps (CDS)

# *Using Bond Yield Spreads to Estimate Hazard Rates*

- Denote $s(T)$ the credit spread for maturity $T$, defined as spread = bond yield – risk-free rate
- Bond yields are quoted as spreads over Treasury rates (risk-free rate)
- Average hazard rate between time zero and time $T$ is approximately (Equation 24.2, p.546)

$$\frac{s(T)}{1-R}$$

where *R* is the recovery rate

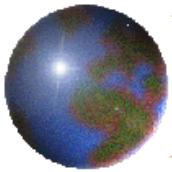
# *Explanation*

- Loss rate at time $t$ is $\lambda(t)(1-R)$
- If the credit spread is compensation for this loss rate it should approximately equal

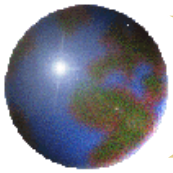
$$\bar{\lambda}(t)(1-R)$$

# *Matching Bond Prices*

- For more accuracy we can work forward in time choosing hazard rates that match bond prices
- Improves on the bond yield approach as it does not assume a constant interest rate
- This is similar to the bootstrap method used for constructing the yield curve from bond prices



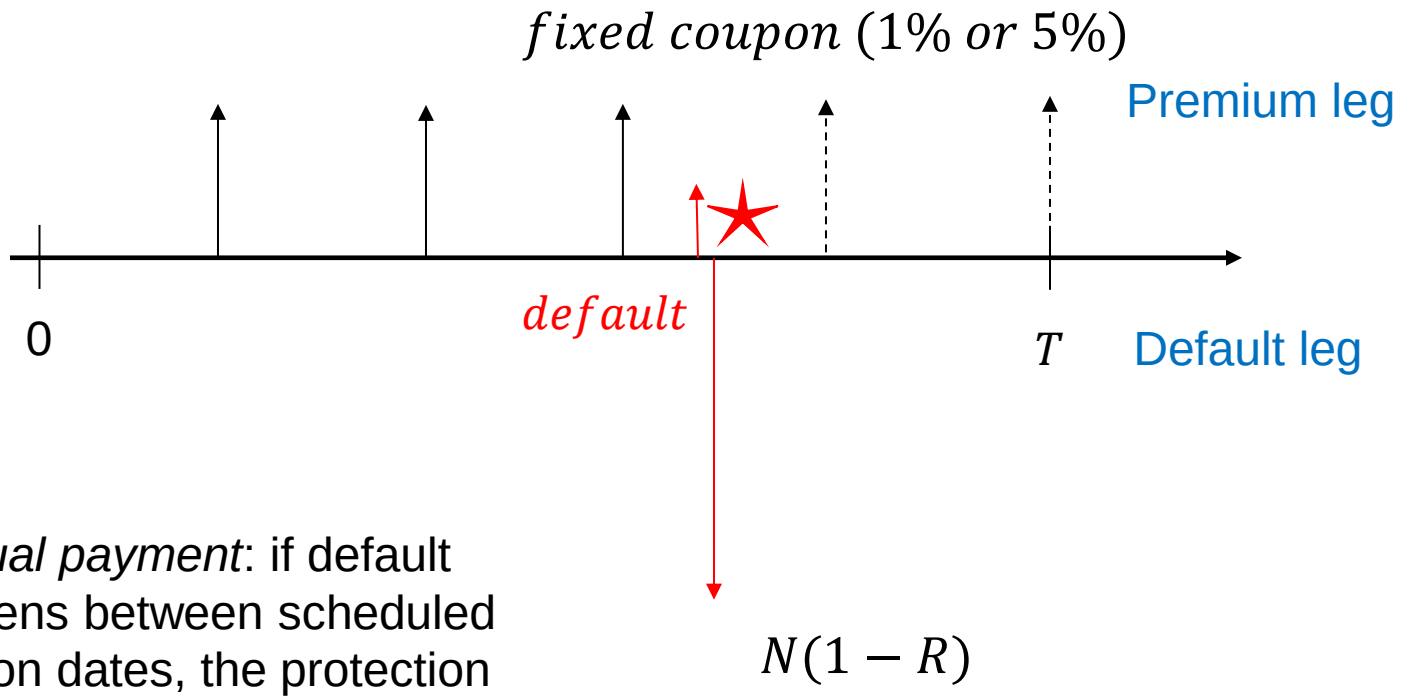
# *Credit Default Swaps*



# *Credit Default Swaps*

- Simplest credit linked derivative. Contract between:
  - Protection buyer - seeks protection against a default/credit event by a particular company or country
  - Protection seller – promises to pay the bond notional in the event of default/credit event
- Similar but not identical to insurance. No insurable interest: anyone can enter into a CDS contract even without owning the bond.

# *Credit Default Swaps*




*Accrual payment*: if default happens between scheduled coupon dates, the protection buyer must pay the accrued amount

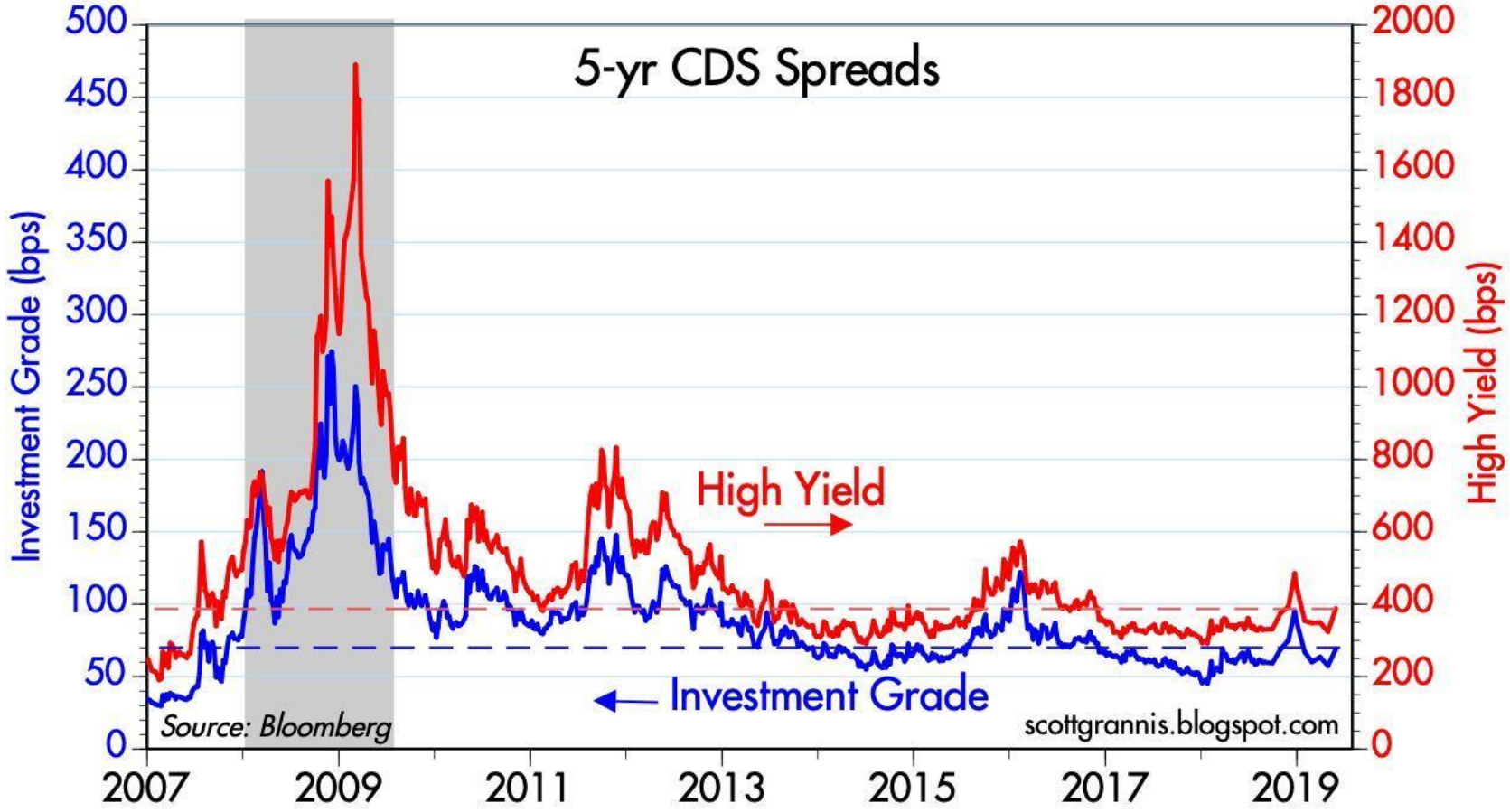
# *CDS Spread*

The CDS Spread (or simply credit spread) is that value of the coupon paid on the premium leg which makes the CDS value equal to zero

CDS price  CDS spread

CDS spreads are quoted daily for most corporations and sovereigns (countries). They express the market view on credit worthiness of a debt issuer.

# *Example*


5-yr CDS Spreads
Investment Grade (bps)
High Yield (bps)
500
450
400
350
300
250
200
150
100
50
0
2000
1800
1600
1400
1200
1000
800
600
400
200
0
2007
2009
2011
2013
2015
2017
2019
High Yield
Investment Grade
Source: Bloomberg
scottgrannis.blogspot.com

# *Other Details*

- Payments are usually made quarterly in arrears
- In the event of default there is a final accrual payment by the buyer
- Settlement can be specified as delivery of the bonds or (more usually) in cash
- An auction process usually determines the payoff
- Suppose payments are made quarterly in the example just considered. What are the cash flows if there is a default after 3 years and 1 month and recovery rate is 40%?

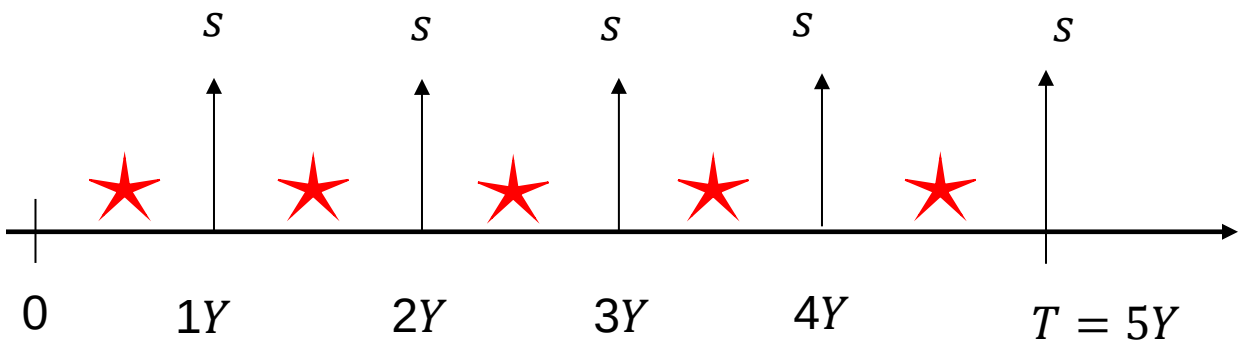
# *Benefits of the CDS Market*

- Allows credit risks to be traded in the same way as market risks
- Can be used to transfer credit risks to a third party
- Can be used to diversify credit risks
- Can be used to compute the market implied probability of default (forward-looking)

# *CDS Valuation Example* *(page 573-575)*

- Use risky discounted cash flows valuation
- Hazard rate for reference entity is 2%.
- Assume payments are made annually, that defaults always happen half-way through a year, and that the expected recovery rate is 40%
- Suppose that the breakeven CDS rate is $s$ per dollar of notional principal

# *Numerical example*




**Assumption**: The bond can default only at the times shown by the stars

# *Unconditional Default and Survival Probabilities* *(Table 25.1)*

| Time (years) | Survival Probability | Default Probability |
|---|---|---|
| 1 | 0.9802 | 0.0198 |
| 2 | 0.9608 | 0.0194 |
| 3 | 0.9418 | 0.0190 |
| 4 | 0.9231 | 0.0186 |
| 5 | 0.9048 | 0.0183 |

# *Calculation of PV of Premium Leg*

***(Table 25.2 Principal=$1)***

| Time (yrs) | Survival Prob | Expected Payment | Discount Factor | PV of Exp Pmt |
|---|---|---|---|---|
| 1 | 0.9802 | 0.9802*s* | 0.9512 | 0.9324*s* |
| 2 | 0.9608 | 0.9608*s* | 0.9048 | 0.8694*s* |
| 3 | 0.9418 | 0.9418*s* | 0.8607 | 0.8106*s* |
| 4 | 0.9231 | 0.9231*s* | 0.8187 | 0.7558*s* |
| 5 | 0.9048 | 0.9048*s* | 0.7788 | 0.7047*s* |
| Total | | | | 4.0728*s* |

# *Present Value of Payments on Default Leg* *(Table 25.3; Principal = $1)*

| Time (yrs) | Default Probab. | Rec. Rate | Expected Payoff | Discount Factor | PV of Exp. Payoff |
|---|---|---|---|---|---|
| 0.5 | 0.0198 | 0.4 | 0.0119 | 0.9753 | 0.0116 |
| 1.5 | 0.0194 | 0.4 | 0.0116 | 0.9277 | 0.0108 |
| 2.5 | 0.0190 | 0.4 | 0.0114 | 0.8825 | 0.0101 |
| 3.5 | 0.0186 | 0.4 | 0.0112 | 0.8395 | 0.0094 |
| 4.5 | 0.0183 | 0.4 | 0.0110 | 0.7985 | 0.0088 |
| Total | | | | | 0.0506 |

# *PV of Accrual Payment Made in Event of a Default.* *(Table 25.4; Principal = $1)*

| Time | Default Prob | Expected Accr Pmt | Disc Factor | PV of Pmt |
|---|---|---|---|---|
| 0.5 | 0.0198 | 0.0099*s* | 0.9753 | 0.0097*s* |
| 1.5 | 0.0194 | 0.0097*s* | 0.9277 | 0.0090*s* |
| 2.5 | 0.0190 | 0.0095*s* | 0.8825 | 0.0084*s* |
| 3.5 | 0.0186 | 0.0093*s* | 0.8395 | 0.0078*s* |
| 4.5 | 0.0183 | 0.0091*s* | 0.7985 | 0.0073*s* |
| Total | | | | 0.0422*s* |

# *Putting it all together*

- PV of expected payments is $4.0728s + 0.0422s = 4.1150s$
- The breakeven CDS spread is given by

  $4.1150s = 0.0506$ or $s = 0.0123$ (123 bps)
- The value of a swap negotiated some time ago with a CDS spread of 150bps would be

  $$4.1150 \times 0.0150 - 0.0506 = 0.0111$$

  per dollar of the principal.

# *Implying Default Probabilities from CDS spreads*

- Suppose that the mid market spread for a 5 year newly issued CDS is 100bps per year
- We can reverse engineer our calculations to conclude that the hazard is 1.63% per year.
- If probabilities are implied from CDS spreads and then used to value another CDS the result is not sensitive to the recovery rate providing the same recovery rate is used throughout

# *CDS and their role in the financial crisis*

- Since anyone (not only bond holders) can enter into CDS contracts, the size of the CDS market exceeded by several times the size of the bond market. The same bond could be insured multiple times
- Lack of transparency: the total number of CDS contracts and liabilities in the event of default were not visible in the market

# *Changes to the CDS market*

- 2009: Standardization of CDS contracts: the CDS "Big Bang". Standard coupons and payment dates. Restructuring added as credit event
- 2013: Central Clearing of CDS contracts. In the US CDS contracts must be cleared on CCPs (Central Counterparties). This improved transparency of the markets
- Basel III and Dodd-Frank legislation pay special attention to CDS and their use