ESSEC

Master in Finance

Advanced Master's in Financial Engineering (MSTF)

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Financial Risk Management

CLASS HANDOUTS

SESSION 6

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Credit Risk

Outline

- Credit Ratings
- Estimation of Default probabilities
- Recovery Rate
- Counterparty Credit Risk in Derivatives
- Credit VaR
- Credit Risk Plus
- CreditMetrics

I. Credit Ratings

- A credit rating is designed to provide information about credit quality.
- In the S&P/Fitch 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"
- Most banks have their own internal ratings systems for borrowers

II. Estimation of Default probabilities

- Approaches for estimating default probabilities
  - using accounting data (e.g., Altman's Z-score)
  - using historical data
  - using credit default swaps
  - using bond prices (or asset swap spreads), and
  - using equity prices (Merton's model).
- Altman's Z-score

$Z=1.2X_1+1.4X_2+3.3X_3+0.6X_4+0.999X_5$

where X_1=*Working Capital/Total Assets*

X_2=*Retained Earnings/Total Assets*

X_3=*EBIT/Total Assets*

X_4=*Market Value of Equity/Book Value of Liabilities*

X_5=*Sales/Total Assets*

If the $Z>3.0$ default is unlikely; if $2.7<Z<3.0$ we should be on alert. If $1.8<Z<2.7$ there is a moderate chance of default; if $Z<1.8$ there is a high chance of default

The Z-score above was calculated from a sample of publicly traded manufacturing companies. Variations on the model have been developed for manufacturing companies that are not publicly traded and for companies not involved in manufacturing.

– Historical Default Probabilities

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

Average Cumulative Default Rates % (1970-2007, Moody's)

	Time (years)						
	1	2	3	4	5	7	10
Aaa	0.000	0.000	0.000	0.026	0.100	0.252	0.525
Aa	0.008	0.018	0.042	0.106	0.178	0.344	0.521
A	0.020	0.094	0.218	0.342	0.467	0.762	1.308
Baa	0.170	0.478	0.883	1.360	1.835	2.794	4.353
Ba	1.125	3.019	5.298	7.648	9.805	13.465	18.426
B	4.660	10.195	15.566	20.325	24.692	32.527	40.922
Caa	17.723	27.909	36.116	42.603	47.836	54.539	64.928

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 0.170% of defaulting by the end of the first year, 0.478% by the end of the second year, and so on

- For a company that starts with a good credit rating default probabilities tend to increase with time
- For a company that starts with a poor credit rating default probabilities tend to decrease with time

III. Recovery Rates

- The recovery rate for a bond is usually defined as the price of the bond a few days after default as a percent of its face value

Recovery Rates; Moody's: 1982 to 2007, issuer weighted

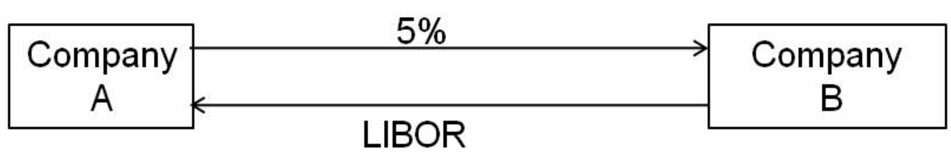
Class	Mean(%)
Senior Secured	51.89
Senior Unsecured	36.69
Senior Subordinated	32.42
Subordinated	31.19
Junior Subordinated	23.95

Recovery rates are significantly negatively correlated with default rates

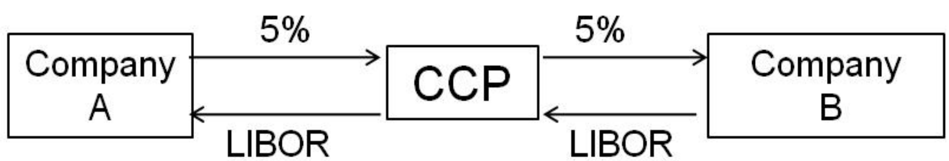
IV. Counterparty Credit Risk in Derivatives

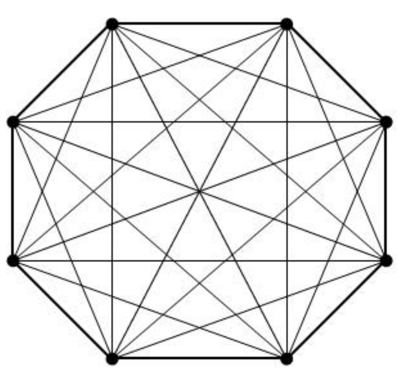
- For Exchange-traded products, margin is required from a trader when the trader could owe money at a future time
- Clearing Arrangements for OTC Derivatives
  - Bilateral clearing
  - Central clearing: a central clearing party (CCP) stands between the two sides

The OTC Trade

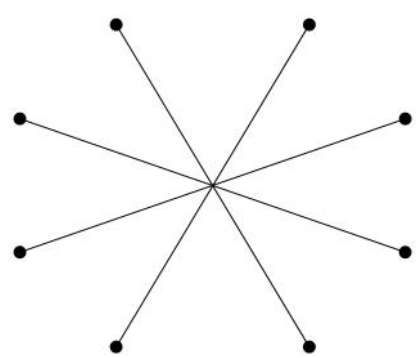


Role of CCP





Bilateral Clearing



Clearing through a single CCP

- Regulations: Standard OTC transactions must be cleared through a CCP (some exceptions); Nonstandard OTC transactions, some FX transactions, and transactions with end users can continue to be cleared bilaterally

– Central Clearing:

- Role of CCP is very similar to that of an exchange clearing house except the products are usually less standard
- It act as intermediary
- It requires initial margin and variation margin from its members reflecting all their transactions (after netting) with CCP.

  Typically, the initial margin is calculated so that it is 99% certain to cover market moves over five days.

  Cash and (in case of initial margin) Treasury instruments are usually accepted as margin.
- If one or both parties to a transaction are not members of the CCP, they can clear the transaction through members.

- The member of CCP contribute to a default fund, which is to be used if the margin balance is insufficient to cover the default loss
- If a member fails to post a margin when required, the member is in default and its positions are closed out.
- The CCP may incur a loss. A waterfall of who bears the loss:
  1. Initial margin of defaulting member
  2. Default fund contributions of defaulting member
  3. Default fund contributions of other members
  4. Equity of CCP
- The existence of CCP could potentially improve the benefit of netting and reduce total risk exposure.
- However, key questions:
  - CCPs should increase netting, because transactions with two different counterparties can be netted if both are cleared through the same CCP, But it will no longer be possible to net standard with nonstandard transactions
  - How many CCPs? Will there be interoperability?

- Bilateral Clearing
  - Usually governed by an International Swaps and Derivatives Association (ISDA) Master agreement (e.g. Netting).
  - This contains a credit support annex (CSA), which defines collateral arrangement: Threshold, Independent Amount, Minimum Transfer Amount, Eligible Securities and Currencies, Haircuts, Two-sided vs. one-sided.
  - New Regulations being implemented between 2015 and 2019 require initial margin and variation margin to be posted for bilaterally cleared transactions between two financial institutions and a non-financial institution when the latter is considered to be systemically important.
  - The initial margin has to provide protection over a 10-day period of stressed market conditions with 99% confidence.
  - Another clause in CSA that is sometimes used to reduce credit risk: Downgrade Triggers.
    - Party A can close out a contract or ask for more collateral when the credit rating of Party B falls below a certain level

- Downgrade Triggers do not provide protection from a big jump in a company's credit rating
- When there are a large number of downgrade triggers, they are counterproductive.

- ISDAs and Defaults:
  - If there is an "event of default" (declaration of bankruptcy, failure to make due payments, and failure to post required collateral), the non-defaulting party has the right to terminate all transactions with the defaulting party after a short period of time.
  - Settlement amount is mid market value of transactions adjusted for bid-offer spread incurred in replacing them
  - Non-defaulting party can keep any collateral posted by defaulting party up to the amount owed.

– Netting
  - Feature of both ISDA Master agreements and CCPs
  - All transactions are considered to be a single transaction in the event of default or for collateral calculations

  - The incremental effect of a new deal on the credit risk exposure to a counterparty can be negative. This may influence the terms offered.
- Consequences of New OTC Regulations:
  - Much more collateral will be needed to support derivatives trading. This collateral will usually have to be cash or government securities
  - This is liable to create liquidity pressures.
  - Rehypothecation: involves using the collateral posted with you by one counterparty to satisfy the collateral demands of another party. It will be restricted under the new rules
  - Swap Execution Facilities (SEFs) and Organized Trading Facilities (OTFs)
    - Whenever possible derivatives have to be traded on electronic platforms.
    - This will create more price transparency. But it may erode the profits of derivatives dealers

- Often a transaction on an SEF or an OTF is automatically passed to a CCP.

- OTC and exchange-traded derivatives markets are becoming more similar to each other as far as the way trading is done, the way transactions are cleared, and the collateral (margin) that has to be posted
- CCPs and Too-Big-To Fail:

  CCPs are much easier to regulate than banks and so moving risks to CCPs may make the financial system safer

– Credit Value Adjustment (CVA)

- A deal calculates CVA for each counterparty with which it has bilaterally cleared OTC derivatives.
- This is an estimate of its expected loss from a default by the counterparty.
- CVA reduces the value of the derivatives, and an increase in the total CVA during a period leads to a decrease in profits for the period, and vice versa.

- Suppose T is the life of the longest derivatives outstanding with a counterparty.

Time	0	t_1	t_2	t_3	t_4	....	t_n=T
Default probability		q_1	q_2	q_3	q_4	....	q_n
PV of net exposure		v_1	v_2	v_3	v_4	....	v_n

$$\text{CVA} = (1-R)\sum_{i=1}^{n} q_i v_i$$ where R is the recovery rate

- The risk neutral default probabilities (i.e., the q_i's) are calculated from credit spreads
- The PV of the net exposure is calculated using Monte Carlo simulation. Random paths are chosen for all the market variables underlying the derivatives and the net exposure is calculated at the mid point of each time interval.
- v_i is the PV of the average net exposure at ith default time
- Collateral agreements must be incorporated into the calculation of v_i. I.e., the net exposure is $max(V-C,0)$,

where V is the market value of outstanding transactions (after netting) to the dealer at the time of default, and C is the collateral posted by the counterparty at the time of default.

- Assuming the net exposure is independent of the probability of default

- Two sources of CVA risk:
  - Changes in counterparty spreads q_i
  - Changes in market variables underlying the portfolio V_i
- Basel III requires CVA risk arising from a parallel shift in the term structure of counterparty credit spreads to be included in the calculation of capital for market risk
- Simplest assumption is that probability of default q_i is independent of net exposure
  - Wrong-way risk occurs when q_i is positively dependent on v_i, increasing CVA. It typically occurs when counterparty is selling credit protection or counterparty is a hedge fund taking a big speculative positions

- Right-way risk occurs when q_i is negatively dependent on v_i. It typically occurs typically occurs when counterparty is buying credit protection or counterparty is partially hedging a major exposure
- One common approach to allow for Wrong-way risk is to use the "alpha" multiplier to increase CVA calculated where the independence assumption is made.

  Basel II sets alpha equal to 1.4 or allows banks to use their own models, with a floor of 1.2

  Estimates of alpha reported by the banks ranges from 1.07 to 1.1

– Debit Value Adjustment (DVA)

- It is the mirror image of CVA.
- DVA the expected cost to the counterparty because the deal might default. It is the counterparty's CVA.
- Accounting value of transactions with counterparty is

No default value – CVA + DVA

- One surprising effect of DVA is when the credit spread of derivatives dealer increases, DVA increases. This increases the dealer's profit.
- Regulators have excluded DVA gains and losses from the definition of common equity in the determination of regulatory capital.

V. Credit VaR

- A one year credit VaR with a 99.9% confidence is the loss level that we are 99.9% confident will not be exceeded over one year
- Under Basel II, banks do not have complete freedom in the way they calculate credit VaR for regulatory purposes.

  Under the IRB approach, banks are allowed to use their own estimates for probabilities of default, and possibly for other parameters as well, but must use the Gaussian copula model and correlations prescribed by Basel II
- However, banks do have complete freedom in the modes they choose when calculating economic capital.
- Banks also have some freedom in the calculation of credit VaR for the purposes of determining the specific risk charge for credit –sensitive items in the trading book.

  For a model to be approved, the concentration risk, spread risk, downgrade risk and default risk must be appropriately captured
- Another regulatory credit risk VaR calculation where banks may have some freedom in their choice of model is the incremental risk charge (reflecting the impact of default, downgrade, credit spread, and liquidity risk for certain items in the trading book).

VI. Credit Risk Plus

- Credit Risk Plus was proposed by Credit Suisse Financial Products in the document "Credit Risk Management Framework"
- It estimates the total loss probability distribution arising from defaults
- A simplified version of the approach:
  - Suppose a bank has N counterparties of a certain type and the probability of default by each counterparty in time T is p.
    The expected number of defaults for the whole portfolio, μ, is given by $\mu = Np$
    Assuming that default events are independent and p is small, the probability of n defaults follows the Poisson distribution
    $$\frac{e^{-\mu}\mu^n}{n!}$$
  - This can be combined with a probability distribution for the losses experienced on a counterparty default (taking account of the impact of netting) to obtain a probability distribution of loss from the counterparties.
    The probability distribution for the losses experienced on a counterparty default can be determined from the current

probability distribution of exposures to counterparties and an estimate of the recovery rate

- In practice, the above analysis can be carried out for different categories and then results combined
- Also, the default rates vary from year to year and a probability distribution of the default rate can be assumed. One approach is to assume a probability distribution for the overall default rate and then assume the default rate for each category is proportional to this.
- Then use Monte-Carlo simulation to find the total loss probability loss function:

  1. Sample overall default rate
  2. Calculate a probability of default for each counterparty catefory
  3. Sample number of defaults for portfolio under consideration
  4. Sample size of loss for each default
  5. Calculate total loss

6. Repeat steps 1-5 many times to build up a probability distribution for the total loss
7. Calculate the required VaR from the total loss probability distribution.

– Note: the effect of assuming a probability distribution for the overall default rate is to build in default correlation (when a high/low overall default rate is sampled, all companies have a high/low probability of default) and make the probability distribution of total default losses positively skewed.

- CreditMetrics was proposed by J.P.Morgan in 1997
- It considers possible rating transition and estimates probability distribution of loss from both downgrades and default.
- A typical one-year ratings transition matrix is :

Initial	Rating at year end								
Rating	Aaa	Aa	A	Baa	Ba	B	Caa	Ca-C	Default
Aaa	91.37	7.59	0.85	0.17	0.02	0.00	0.00	0.00	0.00
Aa	1.29	90.84	6.85	0.73	0.19	0.04	0.00	0.00	0.07
A	0.09	3.10	90.23	5.62	0.74	0.11	0.02	0.01	0.08
Baa	0.05	0.34	4.94	87.79	5.54	0.84	0.17	0.02	0.32
Ba	0.01	0.09	0.54	6.62	82.76	7.80	0.63	0.06	1.49
B	0.01	0.06	0.20	0.73	7.10	81.24	5.64	0.57	4.45
Caa	0.00	0.03	0.04	0.24	1.04	9.59	71.50	3.97	13.58
Ca-C	0.00	0.00	0.14	0.00	0.55	3.76	8.41	64.19	22.96
Default	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	100.00

- Consider a portfolio of corporate bonds. Calculating a one-year VaR for the portfolio using CreditMetrics involves carrying out a Monte Carlo simulation of rating transition for bonds in the portfolio over a one-year period.

  On each simulation trial the final credit rating of all bonds is calculated and the bonds are revalued to determine total credit losses for the ear.

- However, we need to handle the correlation between bonds and calculate credit spread at the end of year
- The CreditMetrics Correlation Model:

  A Gaussian copula model is used to define the correlation between the ratings transitions of different companies

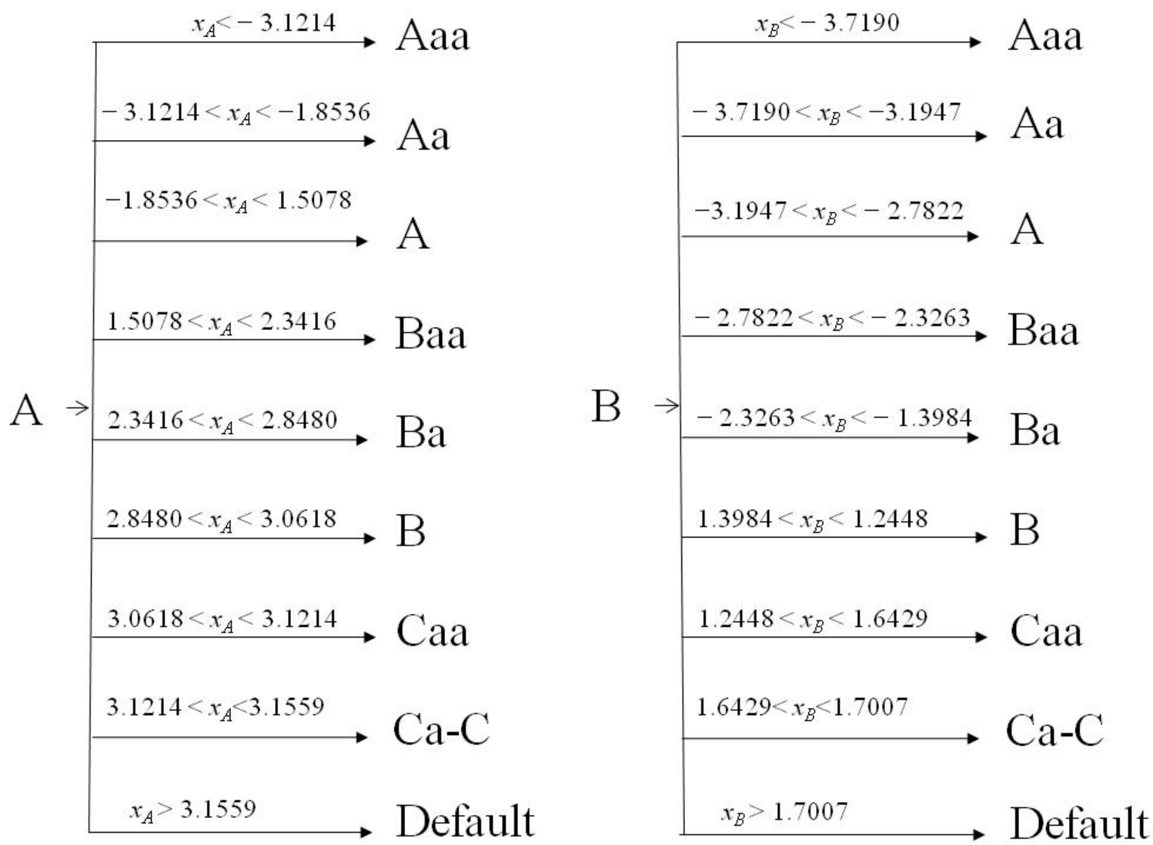
  The copula correlation between the rating transitions for two companies is typically set equal to the correlation between their equity returns.

  Example:

  Suppose we are simulating the rating change of an A-rated and B-rated company over a one-year period. Suppose the correlation between the equity returns of the two is 0.2.

  On each simulation trial, we sample two variables x_A and x_B from standard normal distributions, so that their correlation is 0.2. x_A determines the new rating of the A-rated company and x_B determines the new rating of the B-rated company.

VII. CreditMetrics



– For each bond on each simulation trial one of three things happen:

1. The credit rating of the bonds stays the same.
2. The credit rating of the bond changes. The bond is revalued using a spread of the new rating and calculate the loss.
3. The bond defaults. The credit loss is the exposure at default times (1-R). A recovery rate is sampled, typically from an empirical distribution.

– Time Horizon:

To calculate ten-day VaR, the banks can calculate the 10-day transition matrix (B^{25}=A) and calculate a ten-day loss distribution