VSB – TECHNICAL UNIVERSITY OF OSTRAVA
FACULTY OF ECONOMICS

DEPARTMENT OF FINANCE

Determinace kreditního rizika u portfolia dluhových aktiv
Determination of Credit Risk for Debt Assets Portfolio

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1. Introduction
2. Description of the Financial Risk
3. Description of the Credit Risk Management and Models
4. Determination of Credit Risk by Selected Models
5. Conclusion

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List of Abbreviations
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References:

CUPTON, G. M., C. C. FINGER and M. BHATIA. *CreditMetrics Technical Document.* New York: J. P. Morgan, 1997. 199 p.
FELSENHEIMER, J., P. GISDAKIS and M. ZAISER. *Active Credit Portfolio Management: A Practical Guide to Credit Risk Management Strategies.* Weinheim: Wiley, 2006. 581 p. ISBN 3-527-50198-3.
PEČENÁ, Magda and Petr TEPLÝ. *Credit Risk and Financial Crises.* Praha: Karolinum, 2010. 226 p. ISBN 978-80-246-1872-2.

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The declaration

I hereby declare that I have elaborated the entire thesis including annexes

Ostrava dated …15.04.2021………………… .....Guangyao Ran..........

Contents:

1. Introduction

Nowadays, the importance of financial risks, especially credit risks, is receiving more and more attention. Especially the 2008 global financial crisis. This is mainly due to the structural changes in economics, that is, the increase in the degree of globalization of the world's financial markets. Credit risk refers to the potential loss that a financial institution may cause when the borrower fails to perform its obligations. Therefore, it is important to effectively measure and manage credit risk.

The main purpose of this thesis is to estimate the economic capital of ten selected bond portfolios based on the CreditMetricsTM model, and to estimate the capital required for unexpected losses caused by the credit risk of the Basel Agreement. It provides a possible way to compare the results of the Basel Agreement (including Basel I, Basel II and Basel III) and the CreditMetricsTM model.

The full thesis is divided into five chapters. Chapter 2 and Chapter 3 constitute the theoretical part. The practical part can be found in Chapter 4. Chapter 5 is based on the summary and conclusion of the results.

The theoretical part mainly focuses on different types of financial risks, followed by credit risk management and model descriptions. Give some examples and describe financial risks in detail, including credit risk, market risk, operational risk and liquidity risk. Finally, people discussed different versions of the Basel Agreement on capital adequacy ratios.

In the practical part, an example of a portfolio of ten selected bonds traded on the Frankfurt Stock Exchange was used as economic capital using the CreditMetricsTM model. In addition, according to different versions of the Basel Agreement, different methods have been used to estimate the capital required to make up for unexpected losses. The notional value of the entire portfolio is 10 million Euros, and we have chosen a term of one year. Then, we will conduct a special analysis and comparison of all the results.

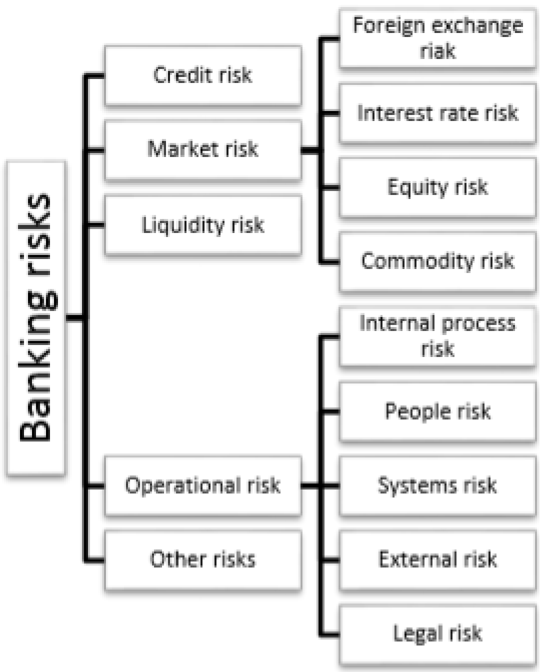
2 Description of Financial Risk

This chapter describes four main types of banking risks, including credit risk, market risk, liquidity risk, operational risk and other types of risk. Among these bank risks, credit risk is the oldest and most risky risk, and we should pay more attention to it.

Banks are widely regarded as stable and dependent. However, risks arise when banks take deposits from one group and use funds to provide credit products to another group. Banks have always faced different types of risks, which often have potentially negative effects on their business. Therefore, in order to minimize bank risk and make the bank operate well, the bank's risk management came into being. This is a historic moment, including the measurement, management and monitoring of bank risk.

There are four typical types of bank risk: credit risk, market risk, liquidity risk and operational risk.

Figure 2.1 Banking risk



2.1 Credit risk

Credit risk is the biggest risk for banks. This happens when the borrower or counterparty fails to meet the contractual obligations. One example is the default or principal of the loan by the borrower. Mortgages, credit cards and fixed income securities can default. Non-performance of contractual obligations may also occur in the areas of derivatives and guarantees.

Although due to the nature of business models, banks cannot be fully protected from credit risk, but they can reduce their exposure in a number of ways. As the deterioration of the industry or issuer is often unpredictable, banks will reduce their exposure through diversification.

In this way, banks are less likely to be overexposed to larger loss categories during a credit downturn. To reduce their exposure, they can borrow money from reputable people, trade with high-quality counterparties, or have mortgages to support loans.

2.1.1 Types of credit risk

Classifying credit risk does help to identify and understand it better. Although credit risk can be classified in different classification methods, the following classification is relatively widely accepted:

- Default risk
- Credit spread risk
- Downgrade risk

Default risk is the chance that a company or individual will be unable to make the required payments on their debt obligation. Lenders and investors are exposed to default risk in virtually all forms of credit extensions. A higher level of risk leads to a higher required return, and in turn, a higher interest rate.

Credit spreads are the spreads between risk-free securities and certain bonds that may have high risk. For example, the difference between Treasury yields and Class A bonds. Generally, due to poor credit, bonds issued by companies must provide higher yields than government bonds. In underperforming economies, spreads tend to widen.

Downgrading risks occur when rating agencies (such as Moody's, Standard & Poor's, and Fitch) have the potential to downgrade a particular debtor after making a loan. If one of the rating agencies downgrades the company, it may be more difficult for the company to pay.

2.1.2 Factor affecting credit risk

In order to quantify credit risk, several major variables need to be considered: the financial condition of the borrower; the severity of the consequences of the default on the borrower and creditors; the historical trend of the default rate; the size of the credit line; and many macroeconomic factors such as the economic environment , Institutional issues, legislation and the natural environment. However, of all these possible variables, four of them are generally considered to have a significant impact on credit risk, namely:

- Probability of default
- Exposure at Default
- Given default loss
- Maturity

Probability of default , also referred to as POD or PD, refers to the opportunity for the borrower to fail to maintain financial capacity within a specific time frame (usually one year). Generally, to compensate for the risk of default, the lender estimates that the higher the borrower's probability of default, the higher the interest rate that the lender will charge the borrower. On the other hand, borrowers can also reduce the risk of default through mortgages or debt.

Credit ratings are often considered indicators of the probability of default. Credit ratings can be assigned to any borrower, such as individuals, companies and sovereign governments. Credit ratings fall into two broad categories, namely internal rating assessments and external rating assessments. Both internal and external systems have similar ratings, that is, they contain both qualitative and quantitative factors.

Internal rating assessments are performed by financial companies themselves, especially banks. In order to ensure the reliable and consistent performance of the rating system, banks wish to conduct their own internal rating assessments to establish a credit rating governance framework.

External rating assessments are performed by credit rating agencies. Credit rating agencies (CRAs) assess the creditworthiness of various borrowers. Rating agencies rate borrowers and debt issuance.

There are two types of long-term credit ratings, including investment-grade and non-investment-grade. *Tab. 2.2* shows the rating scales used by the three major credit rating agencies by Moody's, Standard & Poor's and Fitch.

Tab. 2.2 Long-term rating matrix

	S&P, Fitch	Moody’s
Prime	AAA	Aaa
High grade	AA+, AA, AA-	Aa1, Aa2, Aa3
Upper medium grade	A+, A, A-	A1, A2, A3
Lower medium grade	BBB+, BBB, BBB-	Baa1, Baa2, Baa3
Non-investment grade speculative	BB+, BB, BB-	Ba1.Ba2, Ba3
Highly speculative	B+, B, B-	B1, B2, B3
Substantial risk	CCC+, CCC, CCC-	Caa1, Caa2, Caa3
Extremely speculative	CC, C	Ca
In default	D	C

Standard & Poor's and Fitch use intermediate modifiers for each category between AA and CCC, such as plus () and minus (-), to show their relative position relative to the rating category. These scoring expressions can correspond to the following same rating category as Moody's, for example, AA has about the same meaning as Aa1. Debt and issuers rated BBB or Baa are considered significant speculation with significant uncertainty and are therefore considered non-investment grade. An obligation of rank D indicates default.

Even if a company's credit rating is very good, the credit rating may change due to different financial conditions throughout the year. In the "credit indicator" model, risk should be considered not only as a cause of default, but also as a cause of default value due to debtor upgrade or downgrade. In this case, it is important not only to estimate the likelihood of a default, but also to assess the opportunity for migration. There is an example *Tab 2.3* is the company's one-year transition matrix for Fitch in 2016.

Tab. 2.3 Corporate finance one-year transition matrix in 2016

Global Structured Finance One-Year Transition Matrix: 2016

(%)	AAA	AA	A	BBB	BB	B	CCC	CC and Below	WD	PIF
AAA	75.22	0.42	0.31	0.06	0.15	0.26	—	—	0.76	22.82
AA	8.00	68.80	5.22	0.65	0.10	0.35	—	—	0.35	16.54
A	1.43	8.41	71.88	3.57	0.38	0.38	—	—	0.61	13.35
BBB	0.41	0.78	12.72	64.56	5.19	0.54	0.03	0.14	5.39	10.24
BB	0.29	0.08	1.88	10.85	75.33	2.20	0.86	0.20	1.31	7.01
B	0.10	—	0.10	1.31	27.45	53.87	3.07	1.95	4.28	7.88
CCC	0.06	—	0.11	—	1.34	27.31	56.13	10.54	0.22	4.29

Source: Fitch.

In this transition matrix, it shows the possibility of upgrading and downgrading for each company. Appears in the label. The first column on the left of 2.3 is the credit rating at the end of 2016, and the second row is the credit rating at the end of 2017. For example, a number in the lower right corner of 10.54 shows a credit rating of 10.54%. The probability that the company rating CCC will be converted to the company rating D in 2017 is reduced.

Exposure at Default (EAD) is the total value that a bank will bear when a loan default. Financial institutions use internal rating-based methods to calculate their risks. Banks often use default models for internal risk management to estimate their respective EAD systems. Outside of banking, EAD is called credit exposure.

EAD is the estimated amount of loss that a bank may assume when a debtor defaults on a loan. Banks usually calculate the EAD value for each loan and then use these numbers to determine their overall default risk. EAD is a dynamic number that changes as borrowers repay their lenders.

By default, there are two ways to determine the degree of exposure. Regulators use the first method, called the Fundamental Internal Ratings Base (F-IRB). The second method is called Advanced Internal Ratings Base (A-IRB), which is more flexible and used by banking institutions. Banks must disclose their exposures. The bank will determine this number based on data and internal analysis, such as borrower characteristics and product type. EAD and loss of default (LGD) and probability of default (PD) are used to calculate the credit risk capital of financial institutions.

Loss of default (LGD) is the amount that banks or other financial institutions lose when a borrower defaults on a loan, expressed as a percentage of total exposure at the time of default. The financial institution's total LGD is derived from a review of all outstanding loans using accumulated losses and exposures.

Banks and other financial institutions determine credit losses by analyzing actual loan defaults. Quantifying losses can be complex and requires analysis of several variables. Analysts take these variables into account when reviewing all loans issued by banks to determine LGD. How to account for credit losses in the company's financial statements, including determining credit loss reserves and bad debt reserves.

For example, suppose Bank A loaned $ 2 million to XYZ Company, and the company defaulted. Bank A's loss is not necessarily $ 2 million. Other factors must be considered, such as the amount of assets the bank may hold, whether it has been paid in installments to reduce outstanding balances, and whether the bank uses the court system to compensate XYZ Company. With these and other factors in mind, Bank A may actually lose much less than its original $ 2 million loan.

Determining the amount of loss is an important and fairly common parameter in most risk models. LGD is an important part of the Basel Model (a set of international banking regulations) because it is used to calculate economic capital, expected losses and regulatory capital. The expected loss is calculated by multiplying the LGD of the loan by its probability of default (PD) and the default risk of the financial institution (EAD).

Imagine a borrower getting a $ 400,000 loan for an apartment. After years of repaying the loan in installments, the borrower faces financial difficulties and defaults when the outstanding balance or default risk of the loan is $ 300,000. The bank cancelled the mortgage on the apartment and was able to sell it for $ 240,000. The bank's net loss is $ 60,000 ($ 300,000- $ 240,000), while LGD is 20% ($ 300,000- $ 240,000) / $ 300,000.

In this case, the expected loss will be calculated by the following formula: LGD (20%) x probability of default (100%) x risk of default ($ 300,000) = $ 60,000. Expected losses will differ if financial institutions predict potential losses rather than definite losses. Using the same data as the above scenario, but assuming only a 50% probability of default, the expected loss calculation formula is LGD (20%) x probability of default (50%) x risk of default ($ 300,000) = $ 30,000.

Maturity

The term of a loan is the last important factor affecting credit risk. For better supervision and accounting, three types of loans are provided based on the maturity date: short-term, medium-term and long-term loans. Short-term loans usually have a term of less than one year, while long-term loans have a term of more than five years. The shorter the maturity date, the better the liquidity and the lower the risk.

2.1.3 Ratio indicators of credit risk

Next, we will describe some ratios to measure the credit risk.

NPL ratio is the amount of nonperforming loans over total loans, expressed as a percentage. Nonperforming assets are loans that are past due for 90 days or more. The NPL ratio measures a bank's effectiveness in receiving repayments on its loans. NPL ratio is computed by:

$$\text{NPL ratio} = \frac{\text{NPL}}{\text{Total loan and lease}} \tag{2.1}$$

Provision ratio

Banks need to make some preparations for loans that may default, and we call them loan loss provisions. It is usually shown in the income statement and should be deducted to calculate net income. In this case, we have a reserve ratio (PR)

$$\text{PR} = \frac{\text{Annul provision for loan loss}}{\text{Total loan and lease}}. \tag{2.2}$$

Charge off ratio

After a period of time, due to customer bankruptcy or other factors, some non-performing loans proved to be unpayable. Managers need to remove these worthless assets from the balance sheet. In the process, we have a write-off ratio to measure how many assets are worthless in a year,

$$\text{Charge off ratio} = \frac{\text{Net charge off loans}}{\text{Total loan and lease}}. \quad (2.3)$$

Loan loss allowance ratio

Provision ratios and write-off ratios can only measure credit risk within a year. To measure the bank's total credit risk, we have a loan loss reserve (LLA) ratio. LLA is cumulative.

$$L\text{LA ratio} = \frac{\text{LLA}}{\text{Total loan and lease}}. \quad (2.4)$$

Coverage ratio

Next, we use the coverage ratio (CR) to measure how much non-performing loans can be covered by loan loss reserves. Coverage should be higher than the default loss.

$$\text{Coverage ratio} = \frac{\text{LLA}}{\text{NPL}}. \quad (2.5)$$

2.2 Liquidity risk

Liquidity risk is the risk associated with the shortage of cash and cash equivalent assets and banks have the potential inability to meet its payment obligations. Liquidity refers to the ability to convert assets into cash quickly with a little or no loss.

The risk of changing refinancing rates and the risk of bankruptcy is related to a shortage of funds. In this case, the bank did not have enough money to repay its customers. For example, people prefer to withdraw money during a financial crisis. The outflow of funds is higher than the outflow of funds, resulting in not all customers being able to retrieve funds. This is the risk of bankruptcy. Banks may change their business models to make up for outflows, such as borrowing money from other banks when the term of the loan is longer than the term of the deposit. However, the borrowing rate may be higher than the original interest rate, which is a risk of changing the refinancing rate. Market liquidity risk is related to market liquidity. When market liquidity is very low, the price of the instrument will be lower than its original value.

The following are the most widely used liquidity risk ratios:

$$Liquidity\ ratio = \frac{\text{Cash and due from balances held at other depository institutions}}{\text{Total assets}}, \tag{2.6}$$

$$\text{Liquidity ratio} = \frac{\text{Cash assets and government securities}}{\text{Total assets}}. \tag{2.7}$$

Net stable funding ratio (NSFR)

The ratio indicates whether banks own enough high-quality assets that can be easily converted into cash within one year rather than within the current 30-day limit. Banks rely less on short-term funding, which tends to be more volatile.

$$N\text{SFR} = \frac{\text{Available stable funds}}{\text{Required stable funds}}. \tag{2.8}$$

Liquidity coverage ratio (LCR)

LCR reflects the lowest level of liquid assets when market shocks and the liquidation value of short-term assets should be higher than or equal to unexpected outflows during a given period. The unexpected outflow of funds may be due to the severe downgrade of the credit rating of the institution's public, part of the deposit loss, etc. Can be defined as:

$$\text{LCR} = \frac{\text{Stock of high−quality liquid assets}}{\text{Total net cash outflows over the next 30 calender days}}, \tag{2.9}$$

2.3 Market risk

Market risk means that investors may suffer losses due to factors affecting the overall performance of the financial markets involved. Although market risks can be hedged in other ways, they cannot be eliminated through diversification. Sources of market risk include recession, political turmoil, changes in interest rates, natural disasters and terrorist attacks. Systemic or market risk often affects the entire market at the same time.

2.3.1 Types of market risk

There are four generals market risk categories:

- equity risk,
- interest risk,
- oreign exchange risk,
- commodity risk.

Equity risk is the potential loss caused by adverse changes in prices. Equity, and applies to using the stock price as part of the valuation. Please note that it usually refers to the company's equity through the purchase of stock but does not refer to real estate or properties.

Interest rate risk is one of the market risks associated with changes in interest rates. In this case, interest rate sensitive assets and liabilities are mainly affected, rather than fixed asset liabilities. For example, if interest rates rise, the value of long-term assets will tend to fall. Exceed the value of short-term liabilities. In addition, if interest rates rise, income from long-term assets (such as loans) will be lower than changes in the cost of short-term debt (such as transfers), resulting in reduced bank equity.

The interest risk is the most important market risk and can be identified as:

$$\text{Interest rate risk ratio} = \frac{\text{Interest−sensitive assets}}{\text{Interest−sensitive liabilities}}. \qquad (2.10)$$

Foreign exchange risk

The fluctuation of foreign stock prices also affects the increase or decrease in bank equity. In addition to accepting deposits and accepting loans, another function of banks is to buy and sell foreign exchange on behalf of customers who need to conduct international transactions. Exchange rate-related activities will be affected by exchange rate fluctuations, and there is great uncertainty in the foreign exchange market. In this case, it is important for banks to hedge this foreign exchange risk.

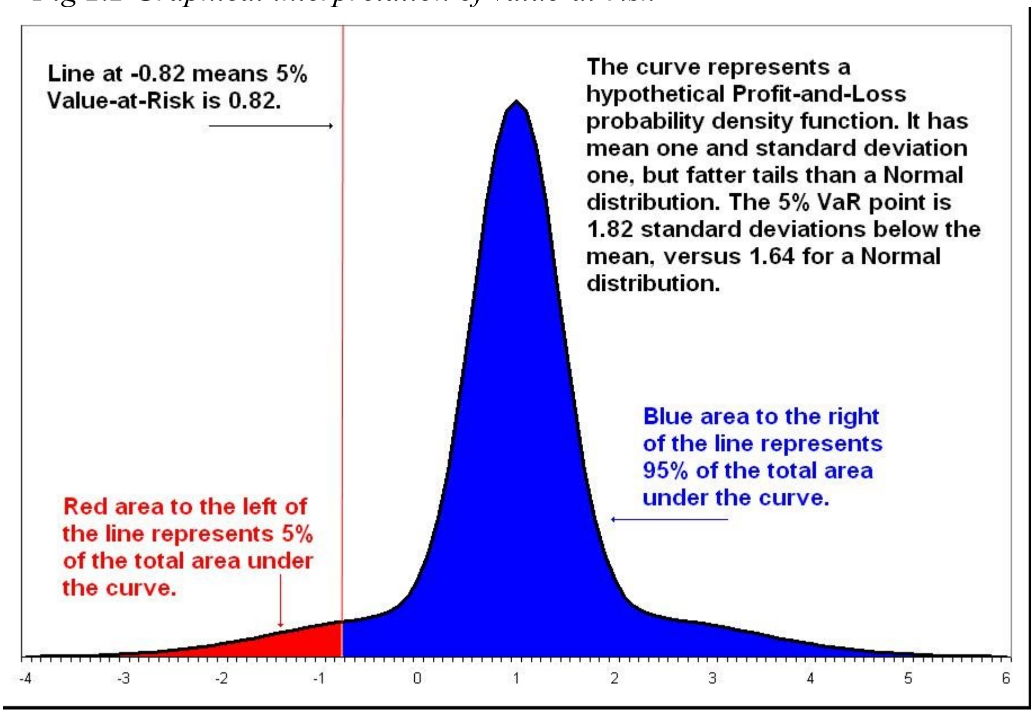
Commodity risks related to adverse changes in commodity prices. Variety The relationship between market supply and demand affects the value of commodities. There are several types considered commodities such as agricultural commodities, industrial commodities, and energy commodities.

2.3.2 Value-at-risk

Value at risk (VaR) measures the risk of investment loss. It estimates how much a set of investments (with a given probability) may be lost (with a given probability) in a given normal time period (such as a day) under normal market conditions. Companies and regulators in the financial industry often use VaR to measure the amount of assets needed to make up for possible losses.

For a given investment portfolio, time range and probability p, p VaR can be informally defined as the maximum possible loss in that time period after excluding all poor results with a maximum probability of the portfolio. Assume market value and no transactions in the portfolio.

Fig 2.2 Graphical interpretation of value-at-risk



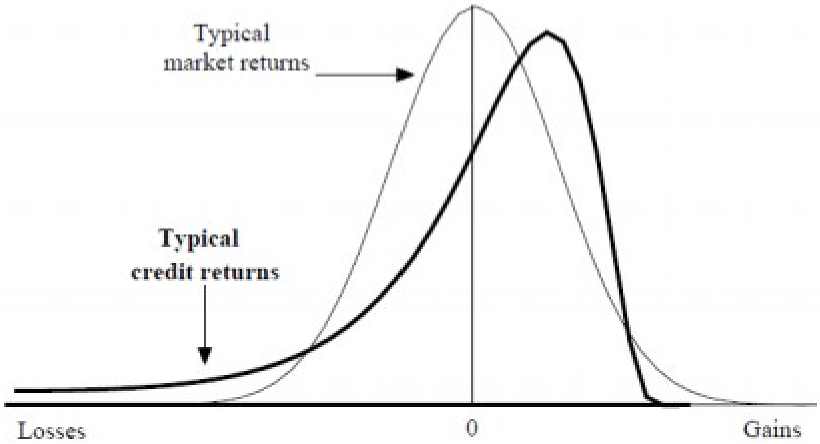
Source: *BESSIS, (2003. 124 p。)*

Note that the horizontal X-axis refers to possible gains and losses, while the vertical Y-axis is the probability of profit or loss. Loss on the left zero and the gain points to the right of zero. In addition, the sum of the lower areas the curves must be one.

2.3.3 Difference between credit risk and market risk

As mentioned earlier, VaR is the most commonly used tool to measure market risk.However, there is no exact way to measure credit risk. The biggest problem is due to credit income distribution and market returns. The return on equity is relatively symmetrical and follows a normal distribution. In this case, the α quantile that reflects market risk VaR can be calculated by the mean and the standard deviation of the value of the portfolio. However, the actual credit returns are high, and the fatness has a larger tail than the normal distribution, which means that losses are more frequent than gains. In this case, estimating the quantiles based on the mean and standard deviation alone is not enough, we need more statistics. *Fig. 2.3* shows a comparison of credit return distributions and market returns.

Fig 2.3 Loss intensity and frequency chart of operational risk events



Source: CUPTON, FINGER, and BHATIA, (1997. 7 p.)

As shown in *Figure 2.3*, the average value of market returns is lower than the average value of credit returns. Due to credit default, the left tail of credit income is higher than the left tail of market income. In this case, with the same confidence level, the potential loss of credit gain is higher than the potential loss of market gain. Managers typically use 95% confidence in market risk, but for credit risk, 99% confidence is more desirable.

2.4 Operational risk

Operational risk summarizes the uncertainty and dangers that companies face when trying to conduct daily business activities in a particular area or industry. A business risk, which may be caused by the collapse of internal procedures, personnel, and systems. This is in contrast to problems caused by external forces such as political or economic events or external forces inherent in the entire market or market segment and is called system risk.

Operational risks can also be classified as various non-systematic risks, which are unique to a particular company or industry. There are several types of operational risk based on different operational events,

- People risk,
- Internal process risk,
- Legal risk,
- External risk,
- Systems risk.

People risk is related to employee error or fraud. This is due to high employee turnover, poor management, insufficient staff training, and excessive reliance on key employees. In this case, employees should be more careful to avoid personal danger.

Internal process risk is the potential loss associated with a bank's internal processes.

Problems arise when processes are poorly organized and inefficient. For example, if the system lacks control, transactions cannot be recorded in the account. Other examples include marketing errors, money laundering, failure to provide reports or documentation, transaction errors and internal fraud.

Legal risk means uncertainty of legal act or contract, interpretation of laws and regulations cause legal risk. For a region's banking industry, this is a very rare but huge impact.

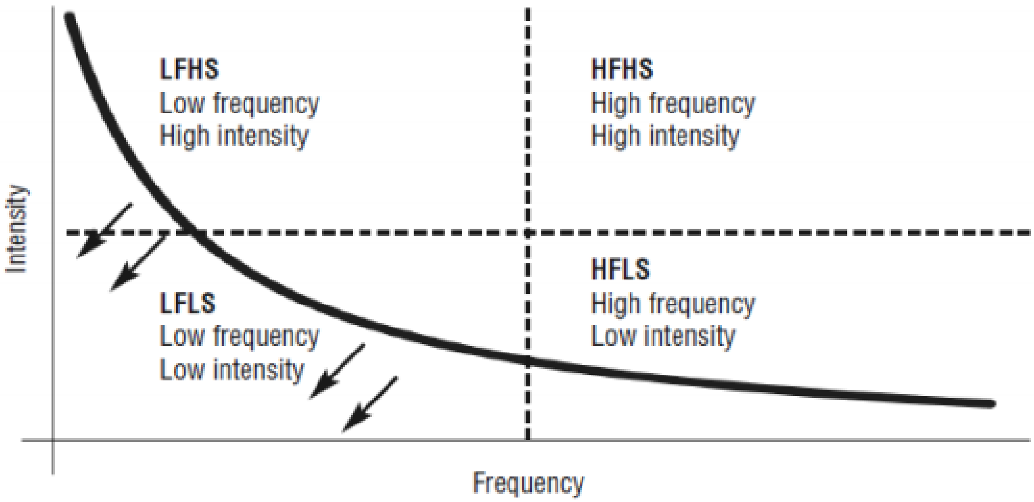
External risk also affect the day-to-day operations of banks. Although the possibility of these events is very rare, it has a significant impact on bank operations. These external events include external events affecting the entire industry, external fraud, and theft, terrorist attacks, and disruption of transportation systems.

Systemic risk is a problem with high-tech systems, such as computer systems. Banks rely on efficient computer systems for their daily operations. Computer system failures can be caused by a variety of reasons, such as data corruption, improper project control, and programming errors.

2.4.1 Operational loss event

There are many events that can lead to operational losses that we cannot afford specification list. In this case, the operating loss can be divided into parts according to its frequency and how much the potential loss is. *Fig 2.4* lists four specific types of tear loss events.

Fig 2.4 Loss intensity and frequency chart of operational risk events



Source: APOSTOLIK, DONOHUE and WENT. (2009. 188 p.)

As shown in *Fig. 2.4*, managers can focus on two types of events, namely high frequency and low intensity loss (HFLS) events and low frequency and high intensity loss (LFHS) events. This is because the cost of monitoring more frequent and more influential events and less frequent and less influential events is higher than the loss itself. For operational risk management, managers will do their best to reduce the loss of high frequency events and reduce frequency of high impact events.

2.5 Other risk types

In addition to the four typical financial risks, there are other types of risks worth mentioning, including regulatory risk, settlement or payment risk, and reputational risk.

Regulatory risk is the potential loss due to changes in government or regulatory agency laws and regulations. As business operating costs increase, such changes often have a negative impact on the business or the market. For example, a government policy requires that an increase in the excise tax on wine will lead to an increase in the cost of wine, and then the price of wine on the market will rise.

Settlement or payment risk refers to the risk of one party failing to deliver assets or making payments to the other party at the time of settlement. Such risks may be related to any time differences in settlement between the two parties. Due to the famous failure of the German bank Herstatt, it can be called "Herstatt risk". After the German banking regulator closed the bank on June 26, 1974, the bank had absorbed its foreign currency receipts in Europe, but did not pay any U.S. dollars, causing a lot of losses to counterparties.

Reputational risk is one of the microeconomic risks usually caused by internal factors in banks. This is a risk or potential threat caused by damage to the reputation of the bank. Factors leading to such losses include the bank's own wrongdoing, bank-related crimes, and even the bank's joint venture partner' mistakes.

3. Description of the Credit Risk Management and Models

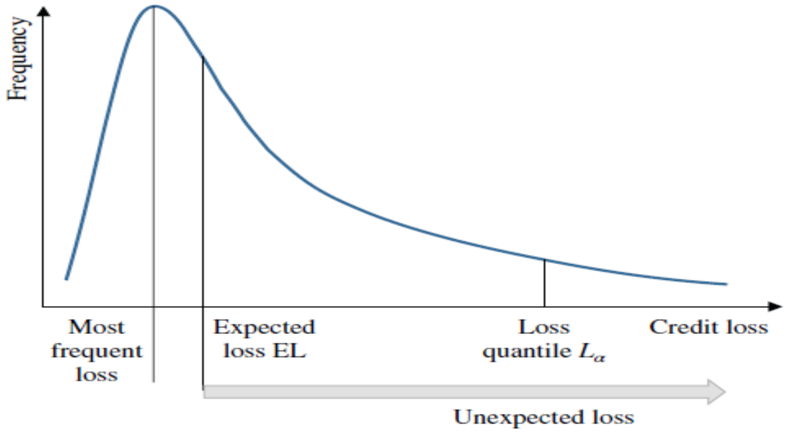
In Chapter 3, several credit risk management methods will be introduced, including scoring models, rating systems, and portfolio models. After that, the main part is the description of the CreditMetrics model to clearly measure the process of credit risk. Finally, we focus on how to calculate the capital requirement and the capital requirement regulation based on the Basel Committee.

3.1 Difference between expected loss and unexpected loss

Before discussing the credit rating model, it is useful to distinguish between expected and unexpected losses. This subsection introduces expected and unexpected losses. Next, the calculation of economic capital is explained below.

As mentioned in Chapter 2, expected loss is driven by three components, PD, LGD, and EAD, as shown in Equation (2.2). This is usually considered the average of the probability distributions of future losses. The lender estimates the expected loss as the actual upfront loss and charges a certain amount of interest to hedge that risk. For accidental losses, this is the reason for the deviation between the actual loss and the expected loss. It is defined as loss volatility around the mean. Similar to the VaR in the market, you can estimate the largest unexpected loss by analyzing the loss distribution with some reliability. The distribution slopes from left to right, and due to the diversification, losses in small portfolios are most common. The loss distribution is shown in *Fig. 3.1*.

Fig. 3.1 Loss distribution of credit risk



Source: BESSIS, (2003. 209 p.)

As you can see in *Fig 3.1,* the distribution is biased to the right and the expected loss is higher than the most frequent loss. Accidental losses can be seen in the right tail, which is higher than expected. Under the confidence level, there is a loss distribution of the distributed quantiles. This is $L\alpha$. Confidence affects the probability of bankruptcy and rating because it indicates the probability of a bank defaulting. Therefore, the appropriate confidence level is very low and should be well below 1%. In addition, you can calculate economic capital. BESSIS *(2003. 209 p.) says "The economic capital can be seen as a buffer against the unexpected loss in excess of the expected loss,,* This can be expressed as:

$$k_a = L_a - EL, \tag{3.1}$$

where $K\alpha$ represents the economic capital with confidence level, EL means the expected loss.

Economic capital reflects the level of capital that banks must maintain to make up for the huge but unexpected losses needed for long-term survival. In our case, economic capital is the difference between the distribution of losses and the quantile of expected losses.

When dealing with diversified portfolios, it is important to clarify the difference between expected and unexpected losses. The total expected loss of an investment portfolio can easily be defined as the total expected loss of each loan, but due to uncertainty, the total expected loss of investment takes into account unexpected losses. However, the volatility of the entire portfolio is usually lower than the sum of the volatility of each bad debt loss. This is because you can reduce unexpected losses by reducing the correlation between each loan (that is, diversifying your portfolio). This means that total credit risk can be significantly reduced by diversifying the investment portfolio with a certain expected return.

3.2 Model of credit risk management

Over the last decade, the world's largest banks have been working to develop advanced systems for modeling credit risk so that banks can better and effectively quantify, aggregate and manage risk. Credit risk management models fall into three main categories: scoring models, rating models, and portfolio models. The mechanisms used to build these models are described in detail in the next subsection.

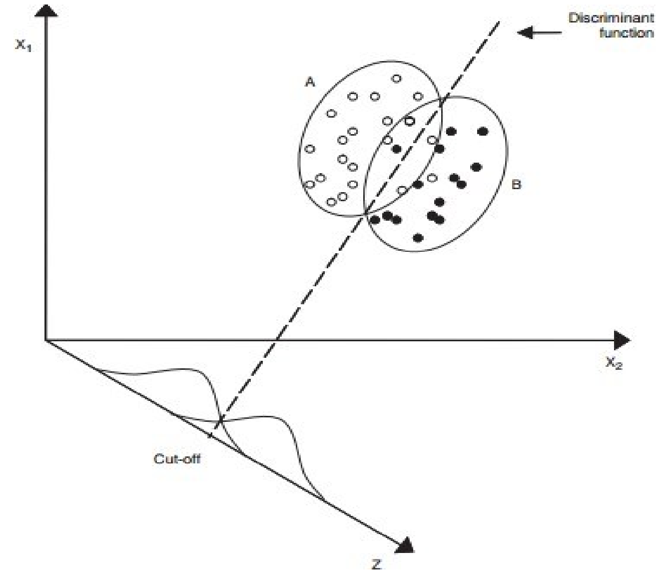
3.2.1 Credit-scoring model

The credit scoring model is a type of statistical model that uses the borrower's key financial and economic indicators to estimate the probability of default by the borrower, discuss its strengths and weaknesses, and analyze its technical characteristics. The result calculated by the scoring model is expressed as a numerical score and is a reliability indicator used to assess the borrower's default probability.

Of the various types of scoring models, the most basic type of scoring model is Linear Discriminant Analysis (LDA), which Fisher is based on deductions designed to identify default economic reasons. I studied it as early as 1936. *Like ANDREA(2007. 287 p) say that "Basically, discriminant analysis is a classification technique which uses data obtained from a sample of companies to draw a boundary that separates the group of reliable ones from the group of insolvent ones,,*

Fig 3.1 below shows a simplified Fisher model. In this model, only two variables, x1 and x2, represent a trusted company (A) and a bankrupt company (B). The score generated by merging the two original variables is displayed on the z-axis.

Fig 3.1: Graphic representation of linear discriminant analysis



Source: ANDREA, and ANDREA, (2007. 288 p).

Linear discriminant analysis constructs the score z as a linear combination of the independent variables x1 and x2. The critical point is the critical point at which a bank decides whether to lend a company. Given n independent variables, the score can be calculated in more general terms as:

$$z = \sum_{j=1}^{n} Y_j \, x_i, \tag{3.2}$$

$$Z_i = \sum_{j=1}^{n} Y_j \, x_{i,i}, \tag{3.3}$$

Note that selecting the coefficient Y_j on this linear combination yields a score of z. This allows you to make the clearest possible distinction between anomalous and healthy businesses.

The most well-known identification score applied to credit risk is the Altman Z Score, developed by Edward Altman for US-listed companies in 1968, and is now offered in the form of Zeta Services. The higher the Z-score, the higher the quality of the company. This is a function of five independent variables, which can be expressed as:

$$Z_i = 1.2 \cdot x_{i,1} + 1.4 \cdot x_{i,2} + 3.3 \cdot x_{i,3} + 0.6 \cdot x_{i,4} + 1.0 \cdot x_{i,5}, \tag{3.4}$$

where: x1 is working capital/total assets, x2 is retained profits/total assets,x3 is earnings before interest and tax/total assets, x4 is market value of equity/book value of total liabilities, x5 is turnover/total assets.

The higher your company's score, the better your financial position and the less likely it is to default. In addition, Ultraman has set key points in its core score to identify whether a company is good or not. The cutoff value is taken as the average of the average z score of a healthy enterprise sample and the average z score of an abnormal enterprise sample, with a value of 1.81. If your company's z score is greater than 1.81, it means that your financial position is very good, based on the Ultraman model.

In addition, z"-score for non-manufacturers is as follow,

$$Z_i = 6.5 \cdot x_{i,1} + 3.26 \cdot x_{i,2} + 6.72 \cdot x_{i,3} + 1.05 \cdot x_{i,4}, \tag{3.5}$$

Compared to the manufacturer's z score, the asset turnover of $x5$ has been completely removed from the model and the weighting factors $x1$, $x2$, $x3$, and $x4$ have been completely changed. In addition, the interpretation of the score has changed. A non-manufacturing company with a z score above 2.9 is considered healthy. If the score is between 1.23 and 2.9, the company needs to be especially careful. According to the Altman model, if the z score is less than 1.23, the default probability is considered high.

3.2.2 Rating system

Discriminant analysis is a quantitative method for estimating the creditworthiness of a borrower. However, there are several qualitative methods that can be used to assess credit risk. The qualitative model is based on a non-automatic evaluation of company data by experts6. Today, these qualitative models are widely used by international rating agencies such as Moody's, Standard & Poor's, and Fitch Rating. In recent years, quantitative and qualitative methods have been used to assess the credit rating of banking systems. The scoring process is divided into three steps.

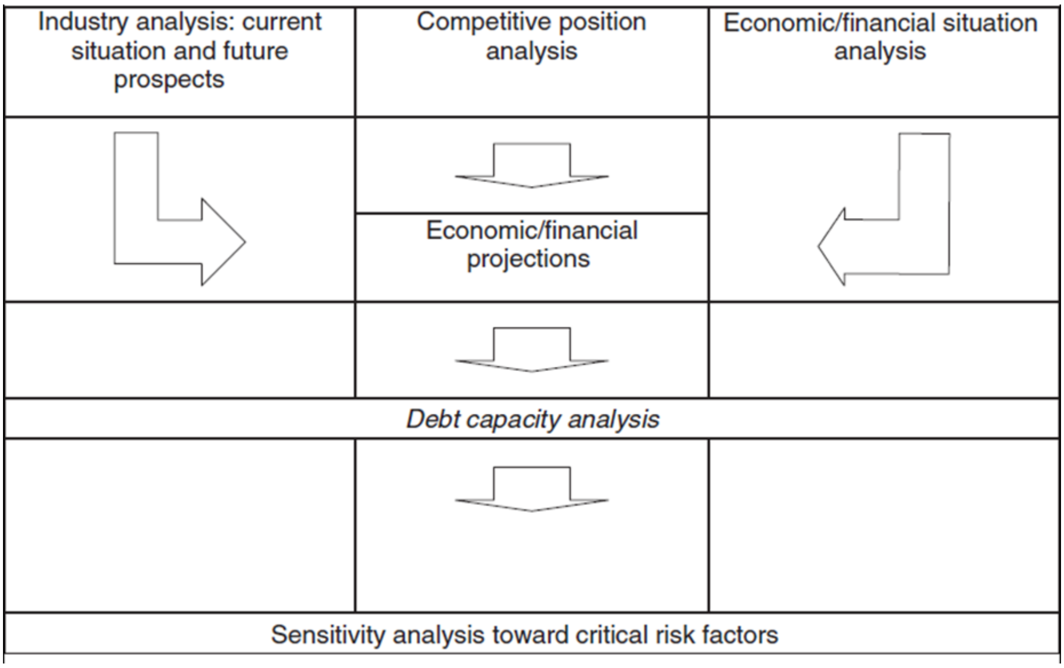
- Score assignment,
- Evaluation quantification,

- Level verification.

Rating assignment

According to various rating agencies, there are two types of credit ratings: the rating agency's credit rating and the bank's internal credit rating. They are both strengths and weaknesses. For example, an institution's rating can avoid the problem of information asymmetry, but an internal credit rating can have more financial information. In either case, rating assignment is to give a rating level that represents an indirect estimate of the default probability. *Fig. 3.3* shows the process of analyzing agent evaluation assignments.

Fig. 3.3 The process of analysis underlying an agency's rating assignment.



Source: ANDREA, and ANDREA, (2007. 375 p.)

Fig. 3.3 summarizes the main stages of the process. After analyzing the company's industry, financial and competitiveness, you can get a forecast of the company's future economy. You can then predict your debt capacity with the help of forecasting by assessing future cash flows. Finally, perform a sensitivity analysis to assess whether your company is functioning well in the worst-case scenarios (decreased demand, reduced efficiency, rising interest rates, and other adverse events).

Rating quantification

Companies will be assigned a latter after rating assignment and there is a problem how to convert the latter-rating into a quantitative element such as probability of default. There are three possible approaches to this problem,

- the statistical approach – based on the score obtained by the scoring model,
- the actuarial approach – based on the actual default frequencies,
- the mapping approach – a link between internal ratings and external ratings.

Statistical methods are based on a credit scoring model for assessing default probabilities. It's fast and convenient, but it has two drawbacks. First, this method relies on a quantitative model, and results are difficult to obtain if only qualitative evaluation by an expert is performed. Second, there are some unrealistic assumptions behind the credit scoring model. As an example of descriptive analysis, we assume that the distribution of input variables is normal.

Actuarial models are based on historical records of default rates. Past default rates can be used as a reference for future default probabilities for borrowers in each category. For example, if the record shows that 1% of the debt allocated to a BB borrower tends to default within a year, then in the future all borrowers with a BB rating will have 1%. You may be in default.

The mapping method is the result of a combination of internal ratings and rating agency ratings. Some banks may establish a relationship between internal ratings and rating agency ratings. For example, 10 out of 10 internal ratings correspond to the AAA level of Standard & Poor's (AAA).

Rating validation

If your company's financial situation changes, you should check your rating system. This means that the rating system should be checked regularly to maintain its effectiveness. The following are some of the quantitative criteria used to assess the validity of the evaluation system.

- The lower the level, the higher the default level.

- The volatility of the default rate is stable over time.
- The percentage of risk exposure that remains at the same level from one year to the next should be high enough.
- The migration rate of migrants to nearby levels must be higher than the migration rate of migrants to distant levels.
- In the years prior to default, most default borrowers should be categorized as a low rating category.

3.2.3 Portfolio model

In addition to the scoring and rating systems described above, a portfolio model developed in the late 1990s can also be used to quantify unexpected losses in credit risk portfolios. The investment portfolio model is designed to determine the maximum loss (so-called "maximum possible loss") that a credit investment portfolio may face if it has some confidence within a given time frame. In particular, there are four portfolio models whick is KMV, CreditRisk+™, CreditPortfolioView™ and CreditMetrics™

The credit risk model is used to estimate the economic capital required to cover the risks associated with a bank's lending activities. There are two basic ways to define credit loss and then quantify credit risk.

Mark to Market (MTM): At the end of the risk range, the borrower is defined as any level, including defaults and transitions. Later, as the borrower's rating level shifts from high to low, risks arise.

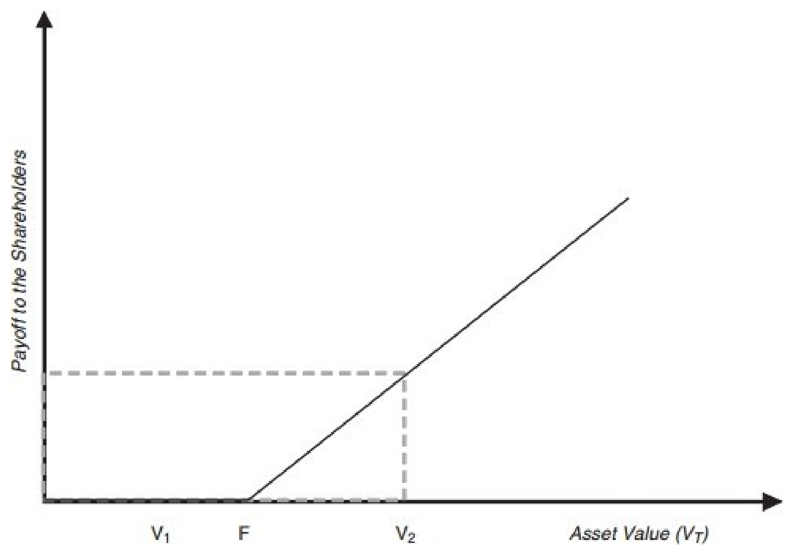
Default model: The model used by financial institutions to distinguish between borrowers who have only two states at the end of the risk range (that is, the default or survival state), where the risk arises from the default.

KMV model was developed by KMV, a California-based company. The acronym KMV comes from the surnames of three founding partners: Steven Kealhofer, John Andrew McQuown, and Oldrich Vasicek. The model is that the stock value (E) is equal to the value of the call option of the company's asset market value, its maturity date is equal to the remaining maturity (T) of the liability, and the exercise price is the bond exercise price. Nominal repayment amount of debt (F) . *Tab. 3.1* and *Fig. 3.4* below shows how two positions each produce the same result at the expiration date (T).

Tab 3.1: Matrix of payoffs as a shareholder or for the purchase of a call option on asset value with a strike price of F

	Payoff at time 0	Payoff at T	
		if $V_T < F$	if $V_T > F$
Shareholder	$-E_0$	0	$(V_T - F)$
Purchase of a call option	$-C_0$	0	$(V_T - F)$

Fig. 3.4: Shareholder payoff profile



Source: ANDREA. and ANDREA (2007. 330 p).

If VT is lower than F, the company goes bankrupt, the remaining assets must be used to repay debt, and shareholders get nothing. Conversely, if VT is greater than F, the company makes a profit and calculates the difference from VTF. This is the amount that shareholders get.

In general, the KMV model requires three steps to indirectly estimate the company's default probability.

$$DP = STD - \frac{1}{2}LTD, \tag{3.6}$$

$$DD = -\frac{V_0 - DP}{V_0 - \sigma_V}. \quad (3.7)$$

where DP is default point, STD means all amount of short-term debt and LTD means long-term debt.DD means distance to default.

. Converts the distance to default into default probability based on fairly accurate empirical correlation based on past actual evidence. The link between DD and PD is called the expected default frequency (EDF).

CreditRisk + ™ is a simple actuarial model developed by Credit Suisse Financial Product in 1997. The model focuses on the possibility of default based on an external Poisson loss distribution. The estimation process is similar to the mathematical process of insurance and is therefore suitable for credit risk. Therefore, as with measuring insurance losses, the two parameters needed to measure credit risk are the frequency of default events and the specific default loss rate. This model is typically used for credit risk assessment of loans.

This model provides the possibility to calculate the probability distribution of the default number over a particular time period based on the Poisson distribution. The probability $p(n)$with n default value can be expressed as:

$$\mu = \sum PD_{J,} \quad (3.8)$$

$$p(n) = \frac{e^{-\mu}\mu^n}{n!}. \quad (3.9)$$

where μ is the expected number of defaults, representing the summarize of j clients' PDs in the portfolio.

CreditPortfolioView™

Developed by Tom Port Wilson in 1997, Credit Portfolio View ™ is based on the business cycle. He argues that immigrant upgrades tend to be more frequent during economic growth. In addition, immigrant downgrades are less frequent and default rates are declining. The situation is the opposite during the recession. In this case, the transition matrix needs to be modified according to some macroeconomic indicators, such as interest rates, employment rates, and real GDP growth, depending on the various stages of the business cycle.

This model allows you to adjust macroeconomic variables based on logarithmic functions and then calculate the default probabilities. The default probability of follow-up in time j or time for companies in the same industry or geographic region that affect the business cycle can be estimated as follows:

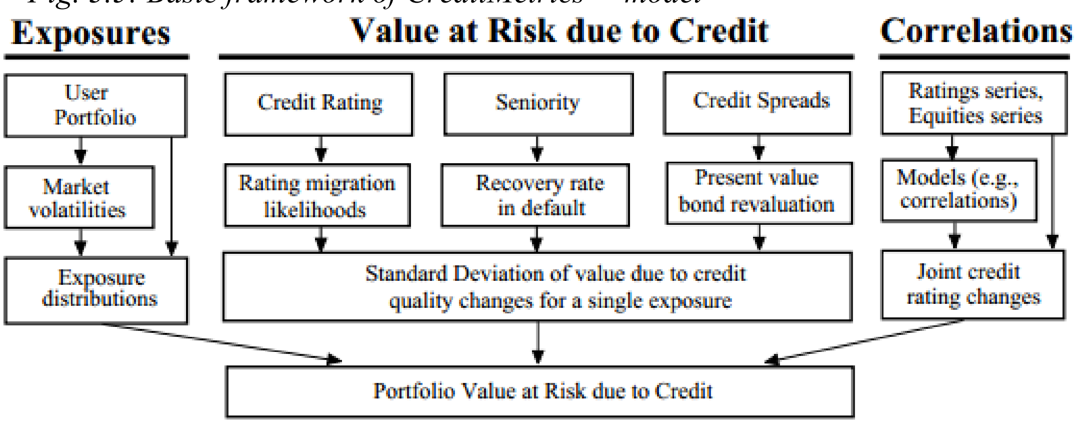
$$P_{jt} = \frac{1}{1+e^{-y_{jt}}}, \tag{3.10}$$

among them, yj and t represent the total value of the company's health index at the time adjusted by macroeconomic factors. This is a linear combination of macroeconomic variables.

3.3 CreditMetrics™

The CreditMetrics ™ model, first proposed by JP Morgan in the United States, is a tool that can be used to estimate the distribution of changes in the market value of credit risk exposures based on data on migration rates, default rates, and borrower spreads. You can then estimate the expected loss (EL) and the unexpected loss (UL) based on this distribution. *Fig. 3.5* below shows a step-by-step introduction to the Credit Metrics ™ model.

Fig. 3.5: Basic framework of CreditMetrics™ model



Source: CUPTON,FINGER, and, BHATIA. (1997. 41 p).

The task of the CreditMetrics model is to measure the VaR of the portfolio by credit by migration analysis. Transition analysis is a method of investigating changes in levels over time through a transition matrix. In this case, the model detects the full range of credit quality transitions, including long-term upgrades and downgrades, and historical data, rather than recent market fluctuations and mere defaults. The next section walks you through the process of the CreditMetrics model step by step.

3.3.1 Single credit risk calculation

This section begins with the process of valuing the VaR generated by the credit of only one debtor. There are three steps to calculating a single credit risk. This is shown as the central part of the frame in Figure 3.5. The three steps are:

- step 1: Credit rating migration,
- step 2: Valuation,
- step 3: Credit risk estimation.

Step 1: Credit rating migration

As mentioned earlier, the risks come not only from the defaults, but also from the model migration. In this case, credit rating transitions are just as important as credit ratings.

The migration procedure is on the *Tab. 2.3*. The main goal of step 1 is to determine the likelihood of moving to a possible credit category within the risk range.

Step 2: Valuation

In this step, the value is determined within the risk range. For a simple one-click, the value would have to be calculated individually for each migration state, which usually requires eight reevaluations. In addition, these eight ratings can be divided into two categories. One is by default and the other is upgraded or downgraded.

In the first case (the default case), the estimated recovery rate depends on the seniority system of the debt. *Tab. 3.2* summarizes the default RRs.

Tab. 3.2 Recovery rates by seniority class (% of face value)

Seniority Class	**Mean (%)**	**Standard Deviation (%)**
Senior Secured	53.80	26.86
Senior Unsecured	51.13	25.45
Senior Subordinated	38.52	23.81
Subordinated	32.74	20.18
Junior Subordinated	17.09	10.90

Source: Carty & Lieberman [96a] – Moody's Investors Services

In this table, you can check the existence of preferred unsecured bonds. The average recovery rate is 51.13% of face value and the standard deviation is 25.45%. In this case, we can see that the LGD of the preferred unsecured bond is 48.87%. The higher the seniority system, the higher the expected recovery rate. For example, the average recovery rate of subordinated bonds is 17.09%, LGD is 82.91%, and the recovery rate is gradually increasing due to the high rating. Under the Basel Agreement, LGD has several regulations. Senior unsecured bonds for companies, sovereigns and banks are assigned a default loss rate of 45%, and subordinated bonds for companies, sovereigns and banks are assigned a default loss rate of 75%. In advanced methods, banks can estimate LGD.

To assess the transition, estimate the changes in credit spreads caused by the transition. In this case, you need to calculate the credit limit within one year. There are two steps to reevaluating. First, you need to get a discount rate that you can use for the discount. Next, calculate the present value within one year of getting the discount rate. The discount rate is clearly not based on the current interest rate, but it reflects the possible value of the market interest rate within a year. Therefore, you can use the previous rate to make the discount. For example, the discount rate can be a futures rate with zero coupons for one year. If you want to know the value of the coming year, you should consider the first payment time of the coupon as the first year and not discount the first payment. Therefore, the present value of a year's credit (PV) can be expressed as:

$$PV = C + \frac{c}{(1+d)} + \frac{c}{(1+d)^2} + \cdots + \frac{c+f}{(1+d)^n}. \tag{3.11}$$

among them, C means coupon, d means discount rate, F means bond face value, and n means maturity time.

The discount rate can be obtained from the forward curve of each rating category. There are two steps to calculating the discount rate. First, you need to find the possibility of moving to each rating category with the initial default values. This can be achieved by the power of the required index annual transition matrix. In this case, if you need to get the n yearly conversion matrix, you need to multiply the first annual conversion matrix by n times by itself. However, the discount rate can depend not only on the probability of moving from the default rating to another rating category, but also on futures rates. The futures exchange rate can be calculated as follows:

$$f_t = \frac{(1+r_t)^t}{(1+r_{t-1})^{t-1}} - 1. \tag{3.12}$$

among them, ft means the futures exchange rate for the year t, and rt means the spot interest rate on risk-free assets such as PRIBOR, LIBOR, EURIBOR, 2W REPO values or interest rate swaps (IRS).

The relationships between forward rate and one-year discount rate can be expressed as:

$$(1 + r_1^d) \cdot (1 - p_1^i) + p_1^i \cdot RR = 1 + f_i, \tag{3.13}$$

where r^d represents the disount rate of a company with assigned rating in one year, p^d is the probability of default in one year, RR is the recovery rate and f_1 is one-year forward rate.

The formula can be extended to 2 years and represents the relationship between the 2-year futures rate and the 2-year discount rate, which is,

$$(1 + r_2^d)^2 \cdot (1 - p_2^d) + (p_2^d - p_1^d) \cdot RR + p_1^d \cdot RR \cdot \frac{(1+f_2)^2}{(1+f_1)} = (1 + f_2)^2, \tag{3.14}$$

Thus, the two-year discount rate can be expressed as:

$$r_2^d = \sqrt{\frac{(1+f_2)^2) - p_1^d \cdot RR \cdot \frac{(1+f_2)^2}{(1+f_1)} - (p_2^d - p_1^d) \cdot RR}{(1-p_2^d)^2}} - 1, \tag{3.15}$$

We extend it to calculation of n-year discount rate, it can be,

$$r_n^d = (1+f_n)\sqrt[n]{\frac{1 - RR\sum_{j=1}^{n}\frac{p_j^d - p_{j-1}^d}{1+f_j}}{(1-p_2^d)}} - 1. \tag{3.16}$$

Suppose a BBB grade bond has a coupon rate of 8%, a par value of € 100 and a maturity of 5 years. Therefore, the annual coupon payment is € 8. label. The following *tab3.3* is an example of an annual forward zero-coupon rate.

Tab. 3.3 Example one-year forward zero curves by credit rating category

Category	**Year 1**	**Year 2**	**Year 3**	**Year 4**
AAA	3.60	4.17	4.73	5.12
AA	3.65	4.22	4.78	5.17
A	3.72	4.32	4.93	5.32
BBB	4.10	4.67	5.25	5.63
BB	5.55	6.02	6.78	7.27
B	6.05	7.02	8.03	8.52
CCC	15.05	15.02	14.03	13.52

Source: CUPTON, FINGER, and BHATIA., (1997. 27 p).

If this BBB bond upgrades to single-A for instance, the value of the bond can be formulated as:

$$\mu_{1,BBB} = 8 + \frac{8}{(1+4.1\%)} + \frac{8}{(1+4.67\%)^2} + \frac{8}{(1+5.25)^3} + \frac{8+100}{(1+5.63)^4} = 116.6$$

If the issuer downgrades to B one year after, the present value one year after will be:

$$\mu_{1,BB} = 8 + \frac{8}{(1+5.55\%)} + \frac{8}{(1+6.02\%)^2} + \frac{8}{(1+6.78)^3} + \frac{8+100}{(1+7.27)^4} = 110.83$$

The difference between one year after present value of BBB and BBclass is 9.44, which is the change of value of credit due to migration. However, there is an uncertainty that the bond will be in which rating class in the future. The eight scenarios can be shown in *Tab. 3.4*.

Tab. 3.4 Distribution of one-year market values of a BBB bond

State at year-end	Present value in one year, μ_j	Probability of migration, p_j (%)	Change, $\Delta V_j = \mu_j - \mu_{Total}$
AAA	118.50	0.02	1.82
AA	118.32	0.33	1.64
A	117.76	5.95	1.08
BBB	116.6	86.93	-0.08
BB	110.83	5.30	-5.85
B	106.75	1.17	-9.93
CCC	91.43	0.12	-25.25
Default	53.80	0.18	-62.88
Mean, μ_{Total}		116.68	

Source: Own calculation.

Step 3: Estimate credit risk

Like other risks to an asset, the credit risk of an investment portfolio can be expressed as the standard deviation of the investment portfolio. Therefore, the main task here is to measure the standard deviation of the present value for one year. According to the tab. In 3.3 you can easily calculate the standard deviation of all eight cases, but you can see that the tab contains the default case. 3.3. As mentioned earlier, downgrading a bond to default creates uncertainty in recovery. The problem is the standard deviation link in the help scene and the standard deviation associated with the recovery rate. The CreditMetrics model can include recovery rate uncertainty through possible standard deviation calculation methods. The calibration of the standard deviation of the portfolio value in each state is as follows:

$$\mu_{Total} = \sum_{i=1}^{n} p_i \, \mu_i, \tag{3.17}$$

$$\sigma_{Total} = \sqrt{\sum_{i=1}^{n} p_i \mu_i^2 - \mu_{Total}^2}, \tag{3.18}$$

Where pi means probability of being in any state, μi means the present value a year from now within each state and $\mu Total$ means the weighted average value of portfolio.

The estimation of standard deviation which incorporated by uncertainty associated with recovery rate is expressed as:

$$\sigma_{Adjusted-total} = \sqrt{\sum_{i=1}^{n} p_i({\mu_i}^2 + {\sigma_i}^2) - {\mu_{Total}}^2}, \tag{3.19}$$

Note that the portfolio expectations are the same as before. The only difference is the calculation of the standard deviation. Here we have added one that represents the risk for each rating level. If the bond has not been downgraded to default, it will be 0. You can find the number when i is equal to 8 in the *Tab 3.2* depends on seniority.

The final result of our stand-alone portfolio with a senior secured BBB-rated bond is shown as *Tab. 3.4* below,

Tab 3.5 Calculation volatility in value due to credit quality changes

Year-end rating	Probability of state (%)	New bond value plus coupon ($)	Probability weighted value ($)	Difference of value from mean ($)	Probability weighted difference squared
AAA	0.02	118.50	0.02	1.82	0.0010
AA	0.33	118.32	0.39	1.64	0.0139
A	5.95	117.76	7.01	1.08	0.1394
BBB	86.93	116.60	101.36	-0.08	0.1726
BB	5.30	110.83	5.87	-5.85	1.3030
B	1.17	106.75	1.81	-9.93	0.9051
CCC	0.12	91.43	0.11	-25.25	0.6253
Default	0.18	53.8	0.10	-62.88	4.7594
	Mean =	$116.68		Variance =	11.52
				Standard deviation =	3.394

In addition, there is another convenient way to measure credit risk by calculating percentile levels. Now, to measure credit risk, there is a 1% chance of determining the first percentile level of a bond. In this way, we focus on the cumulative probability of starting at the bottom of the grade level and moving to the AAA grade level by default. The meaning of the 1st percentile level is a value of 1% or more from bottom to top first. From now on, you can see the cumulative probability and present value of the bond one year later in the *Tab. 3.6* below.

Tab. 3.6 Value and cumulative probabilities

State at year-end	Difference of value from mean	Probabilities	Cumulative probabilities	Present value a year from now
Default	-62.88	0.18%	0.18%	53.80
CCC	-25.25	0.12%	0.30%	91.43
B	-9.93	1.17%	1.47%	106.75
BB	-5.85	5.30%	6.77%	110.83
BBB	-0.08	86.93%	93.70%	116.60
A	1.08	5.95%	99.65%	117.76
AA	1.64	0.33%	99.98%	118.32
AAA	1.82	0.02%	100.00%	118.50

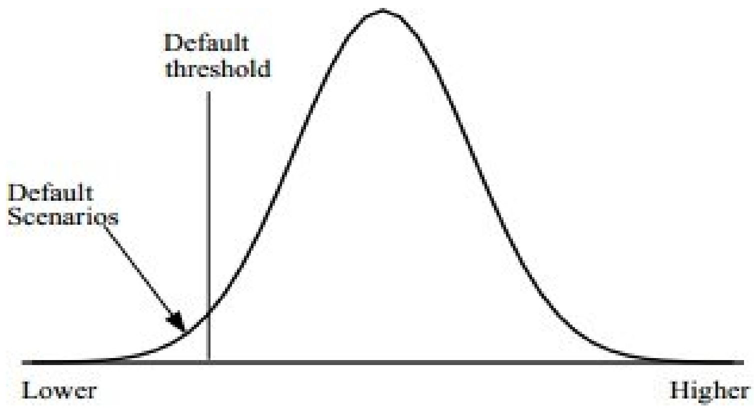
Source: Own calculation.

We will explain in the tab. In *tab 3.6*, when a BBB debtor is downgraded to B debt, the cumulative probability is initially higher than 1%. In this case, one year later, the present value of the portfolio is € 106.75, which is € 9.93 lower than expected. When using the 95% confidence level, the following evaluation levels should be noted: Cumulative probability initially exceeds 5%. That is, the BB interest rate is € 110.83, which is € 5.85 lower than expected. Comparing these two confidence levels, downgrading to B level is riskier than downgrading to BB level. This can be expressed as the difference between the expected value and € 9.93, which is much higher than € 5.85.

3.3.2 Credit quality correlation

Assuming zero correlation is usually too simple and impractical. This is because company rating changes and defaults are caused by some common factors (business cycles, interest rate changes, commodity price changes, etc.) , which means estimating the credit quality correlation parameters. Let us regard default as a function of the company value as *Fig 3.4* below:

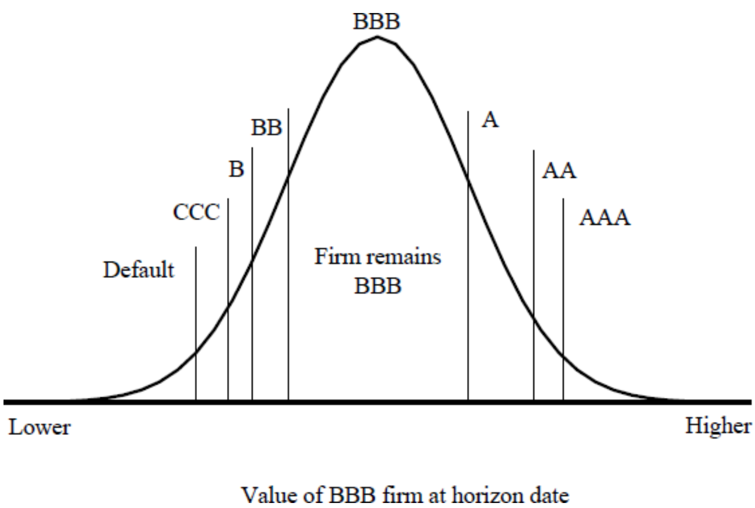
Fig. 3.4: Model of company value and its default threshold



Source: CUPTON, FINGER, and, BHATIA. (1997. 37 p).

If the future value of the company is below the default threshold, the company will not be able to meet its obligations and will lead to default. However, the default probability estimation here is not important in the Credit Metric model, as one of the prerequisites of the model is to always assign a credit rating to each debtor. Needs to be extended to include rating changes. The extension links the default threshold to the credit rating transition threshold. Details are shown in *Fig 3.5* below.

Fig. 3.5 Model of firm value and generalized credit quality thresholds



Source: CUPTON, FINGER, and, BHATIA., (1997. 38 p).

As shown in *Fig 3.5*, the default rating threshold is the same as the default threshold in *Fig 3.4*, except that a credit rating is assigned to each value of the company in the time frame. If the future value of the asset falls below this threshold, there is a default result. However, if future assets are between the CCC and BB thresholds, bank analysts may downgrade the company's stock to a BB rating. In this case, you can easily map relatives in the credit rating category to asset values if you have specific numbers on both the horizontal and vertical axes. Therefore, all we need to do is measure changes in the value of an asset and explain its changes in its credit rating. To do this, we need to determine the other two parameters: the mean value of the asset value μ and the standard deviation σ of the asset return. This is because the probability distribution of future asset returns is normal. Merton model. Later, it became possible to establish a connection between the asset threshold and the company's migration probability. Use $Zdef$, $ZCCC$, $ZBBB$, etc. to represent the asset's revenue threshold. For example, you can calculate the probability of each of these events that occur in the BB rating and is associated with the probability of migration. *Tab. 3.7,*

Tab 3.7: Transition probabilities and thresholds for a BB-rated company

Rating	**Probability from the transition matrix (%)**	**Cumulative Probability**	**Threshold**
Default	$\phi(Z_{def}/\sigma)$=1.06	1.06	-2.3σ
CCC	$\phi(Z_{CCC}/\sigma)$- $\phi(Z_{def}/\sigma)$=1	2.06	-2.04σ
B	$\phi(Z_{B}/\sigma)$- $\phi(Z_{CCC}/\sigma)$=8.84	10.90	-1.23σ
BB	$\phi(Z_{BB}/\sigma)$- $\phi(Z_{B}/\sigma)$=80.53	91.43	1.37σ
BBB	$\phi(Z_{BBB}/\sigma)$- $\phi(Z_{BB}/\sigma)$=7.73	99.16	2.39σ
A	$\phi(Z_{A}/\sigma)$- $\phi(Z_{BBB}/\sigma)$=0.67	99.83	2.93σ
AA	$\phi(Z_{AA}/\sigma)$- $\phi(Z_{A}/\sigma)$=0.14	99.97	3.43σ
AAA	1-$\phi(Z_{AA}/\sigma)$=0.03	100	

As shown in *Tab 3.7*, if the future asset value is between -1.23σ (ZB) and 2.39σ ($ZBBB$), the change is not enough to justify the rating change and the company stays in the BB. I will. If the asset value is higher than 2.39σ, the debtor will upgrade to a BBB rating.

We can use the same method to calculate the A bond threshold, and the results are shown in the following table.

Tab 3.8: Transition probabilities and thresholds for a A-rated company

Rating	**Probability from the transition matrix (%)**	**Cumulative Probability**	**Threshold**
Default	$\phi(Z_{def}/\sigma)$=0.06	0.06	-3.24σ
CCC	$\phi(Z_{CCC}/\sigma)$- $\phi(Z_{def}/\sigma)$=0.01	0.07	-3.19σ
B	$\phi(Z_{B}/\sigma)$- $\phi(Z_{CCC}/\sigma)$=0.26	0.33	-2.72σ
BB	$\phi(Z_{BB}/\sigma)$- $\phi(Z_{B}/\sigma)$=0.74	1.07	-2.3σ
BBB	$\phi(Z_{BBB}/\sigma)$- $\phi(Z_{BB}/\sigma)$=5.52	6.59	-1.51σ
A	$\phi(Z_{A}/\sigma)$- $\phi(Z_{BBB}/\sigma)$=91.05	97.64	1.98σ
AA	$\phi(Z_{AA}/\sigma)$- $\phi(Z_{A}/\sigma)$=2.27	99.91	3.12σ
AAA	1-$\phi(Z_{AA}/\sigma)$=0.09	100	

The evolution of the two credit ratings is based on the following assumptions: The returns on the two assets are related, normally distributed, and there is only a specific correlation between the returns on the two assets. Therefore, the covariance matrix of the bivariate normal distribution can be calculated as follows:

$$\Sigma = \begin{pmatrix} \sigma^2 & \rho\sigma\sigma' \\ \rho\sigma\sigma' & \sigma'^2 \end{pmatrix} \quad , \tag{3.20}$$

Then, assuming that the correlation coefficient ρ of the two asset returns is not equal to zero, the likelihood rate for the two companies to maintain their current credit rating is between $Z_B$and Z_{BB}, while the asset return for the A-rated company falls between Z_{BBB} and Z_A.

$$\Pr\{Z_B < R < Z_{BB}, Z_{BBB} < R < Z_A\} = \int_{Z_B}^{Z_{BB}} \int_{Z_{BBB}}^{Z_A} f(r, r'; \Sigma)(dr')\,(dr), \tag{3.21}$$

where $f(r, r'; \Sigma)$ denotes the density function for the bivariate normal distribution with covariance matrix Σ, and r and r' denote the values that the two asset returns may take on in the specific intervals.

3.4 Regulation of capital requirements

In this chapter, the capital requirements of some banks are developed in accordance with the Basel Agreement. Focuses on the calculation of capital requirements under Basel Agreement I, an extended version of the calculation of capital requirements under Basel Agreement II in several ways, and measures to enhance bank supervision, supervision and risk management after the financial crisis. Guess. Basel III.

The Basel Agreement was first proposed by the Basel Committee in 1988. The original name of the Basel Committee was the Banking Supervisory Commission, which was established at the end of 1974 by the Governor of the Central Bank of Group 10. Oversight of the Basel Agreement. A banking system that improves financial stability by improving the quality of global banking supervision. This set of international standards for banking supervision is the most notable and is a groundbreaking publication on capital adequacy agreements, commonly referred to as "Basel I", "Basel II" and more recently "Basel Agreement III". These three protocols are introduced in the next section.

3.4.1 Basel I Accord

In the early 1980s, capital adequacy ratios of major international banks continued to deteriorate, international risk continued to increase, and the outbreak of the Latin American debt crisis also drew the Commission's attention. In 1988, with the support of the Governor of Group 10, the Committee issued a standard for measuring capital adequacy ratios, including a weighted risk measurement method. This standard is called "Integration of International Capital Metrics and Capital Standards" and is commonly referred to as the "Basel Capital Agreement".

Under the Basel Capital Agreement, they first described the components of capital. There are two types of regulated capital.

Tier 1: Core capital (basic capital) includes permanent shareholders' equity and disclosure reserve, and goodwill is deducted. Permanent shareholders' equity capital includes common stock and permanent non-cumulative preferred stock, and disclosed reserves include retained earnings or other surplus (stock premiums, retained earnings, general reserves, statutory reserves). Includes budget increases due to (such as money).

Tier 2: Supplementary capital includes non-disclosure reserves, revaluation reserves, general reserves, hybrid debt capital instruments and subordinated bonds. Non-disclosure reserves include some of the after-tax surplus accumulated from undistributed profits and banks in certain countries may be allowed to retain non-disclosure reserves. The revaluation reserve includes, for example, the implicit value generated by the revaluation of a bank's fixed assets according to legal requirements in a particular country / region, and the valuation of long-term stocks on the balance sheet. Based on past acquisition costs. A hybrid-capitalized product is a product that includes equity capital and liabilities. Subordinated debt includes capital investment in traditional unsecured subordinated debt. The minimum initial fixed period is 5 years or more, and the period of redeemable preferred stock is limited.

There are some restrictions on Tier 1 and Tier 2 capital. First, Tier 1 capital must be greater than or equal to Tier 2 capital. Second, subordinated debt must be less than half of Tier 1 capital. Third, the revaluation reserve from subsequent unrealized securities returns will be offset by 55%.

Second, the Commission believes that different weighted risk ratios are needed when capital is associated with different types of assets. You can use these weighted risk ratios to calculate risk-weighted assets (RWA) and further calculate capital adequacy ratios through the risk-weighted capital measurement method. Weighted risk ratios are divided into four categories: 0%, 20%, 50% and 100%. The less weight you have, the lower your risk. For example, cash is considered to be allocated as a non-risk asset with a weighted risk ratio of 0%. Annex 1 shows a specific item for each weight.Annex 1

Then the risk-weighted assets form N items can be computed as follow:

$$\mathrm{RWA} = \sum_{I=1}^{N} W_I \cdot \mathrm{EAD}_i, \tag{3.22}$$

where W_I is the risk weight of the item and EAD_i is the exposure at default of the item.

At last, Committee presented a series of target standard ratio of capital adequacy, which can be expressed as follows,

$$\text{Tier 1 ratio} = \frac{\text{Tier 1 capital element}}{\text{RWA}} \geq 4\% \tag{3.23}$$

$$\text{Capital adequacy ratio} = \frac{\text{Tier 1 captital+Tier 2 capital}}{\text{RWA}} \geq 8\%, \tag{3.24}$$

The capital adequacy ratio is expressed as a common minimum standard which international banks in member countries would be expected to observe form the end of 1992. However, this equation presented here only reflects credit risk and there was a modified version of capital adequacy containing market risk by 1996 Market Risk Amendment. The modified version of capital adequacy ratio can be given by,

$$\text{Capital adequacy ratio} = \frac{\text{Tier 1 captital+Tier 2 capital}}{\text{RWA+}(12.5*\text{CR}_\text{m})} \geq 8\%. \tag{3.25}$$

where CR_m is capital requirement for market risk.

3.4.2 Basel II Accord

In June 2004, the Commission issued a revised capital framework, commonly referred to as "Basel II". Under Basel II, the Commission has improved the framework for addressing new risks, operational risks, rather than credit or market risks. In addition, there are several ways to measure credit risk, market risk, and operational risk. This avoids Basel I's significant weakness of assigning the same risk weights to different grades of loans. The revised Basel Agreement framework includes three pillars:

- First pillar: Minimum capital for credit risk, market risk and operational risk，
- Second Pillar: Venture Capital Supervision and Review，
- Third pillar: Market discipline.

Pillar 1: Minimum capital for credit risk, market risk and operational risk

The first pillar of Basel II is to provide standardized credit risk, market risk, and operational risk rules through regulated capital and risk-weighted assets. This is the first attempt to allocate regulatory cost of capital to operational risk management. In Basel I, regulated capital is divided into Level 1 and Level 2, and regulated capital expenditures are allocated to credit risk management. According to a press release of the 1996 Market Risk Correction Act, the Commission correlated market risk with regulated capital while at the same time proposing a third-tier capital, which is another type of capital. Tier 3 capital may be used at the discretion of national authorities, such as short-term subordinated debt and tertiary capital. The upper limit is 250% of the bank's Tier 1 capital that supports market risk. The calculation of total RWA also depends on the additional capital requirements for operational risk. This can be expressed as:

$$RWA_{\mathrm{Total}} = \mathrm{RWA_c} + 12.5 \cdot (\mathrm{CR_m} + \mathrm{CR_o}), \qquad (3.26)$$

Where RWA_c means the risk-weighted -assets for credit risk, CR_m denotes the capital requirement for market risk and CR_o is the capital requirement for operational risk.

The capital ratio can be computed as follow,

$$\text{Capital adequacy ratio} = \frac{\text{Tier 1} + \text{Tier 2} + \text{Tier 3}}{\mathrm{RWA_c} + 12.5 * (\mathrm{CR_m} + \mathrm{CR_o})} \geq 8\%. \qquad (3.27)$$

Note that tier 3 capital can only be used to measure the capital requirements of market risk. In this case, for credit risk, the capital of eligibility levels 1 and 2 should be at least $8\% \cdot RWA_c$, for market risk, the capital of eligibility levels 1, 2, and 3 should be higher than CR_m.

In addition, Basel II defines several methods for estimating bank risk for each type of risk. It can be summarized in the following *Tab. 3.9.*

Tab. 3.9 Methods for calculation capital according to Basel II

	Credit risk	Market risk	Operational risk
Approaches	• Standardized approach • Foundation internal ratings-based rating (IRB) approach • Advanced IRB approach	• Standardized Approach • Internal model approach	• Basic indicator approach • Standardized approach • Advanced measurement approach
Result	Risk-weighted asset value for credit risk	Market risk capital charge	Operational risk capital charge

Source: APOSTOLIK, DONOHUE and. WENT, (2009. 203 p).

Standardized approach

In the standardized approach, risk-weighted assets are split according to the formal credit ratings associated with a set matrix as *Tab. 3.10* shows.

Tab. 3.10: Capital requirement risk weights under Basel II

	Government	Public sector	Banks	Corporations
AAA to AA-	0%	20%	20%	20%
A+ to A-	20%	50%	50%	50%
BBB+ to BBB-	50%	100%	100%	100%
BB+ to B-	100%	100%	100%	100%
B+ to B-	100%	150%	150%	150%
Below B-	100%	150%	150%	150%
Unrated	100%	100%	100%	100%

Source: BIS.

In Basel II, the OECD stipulates that government risk weights range from 0% to 150% and public sector, banking, or corporate risk weights range from 20% to 150%.

In Basel 1, OECD banks were implicitly assumed to have lower credit risk than businesses. In other words, the OECD bank has a risk weight of 20% and the company has a risk weight of 100%. However, as shown in Table 3.11 above, the treatment of banks and businesses is high. For example, if a bank has a rating between AAA and AA, the risk weight assigned to that bank will be 20%.

Internal ratings-based (IRB) approach

In an internal rating-based approach, risk-weighted assets follow an internal risk assessment, especially for banks that must have their own internal system to classify loans by PD band, as shown in *Tab. 3.11*. It will be classified. IRB methods can be divided into basic IRB methods and advanced IRB methods.

Tab. 3.11: Capital requirements under specified PD bands (%)

	PD band	Basel I	Standard approach	IRB foundation approach
AAA	0.03	8.0	1.6	1.13
AA	0.03	8.0	1.6	1.13
A	0.03	8.0	4.0	1.13
BBB	0.20	8.0	8.0	3.61
BB	1.40	8.0	8.0	12.35
B	6.60	8.0	12.0	30.96
CCC	15.00	8.0	12.0	47.04

Source: BIS.

3.4.3 Basel III Accord

According to Basel II, risk measurement relies heavily on rating agencies' credit ratings, preventing banks from identifying risky assets. For example, asset-based securities with underlying assets, including mortgages, loans and other securities, have emerged and traded in the secondary market. Such securities are rated by rating agencies and have the same rating category model as the basic asset rating categories, such as AAA and AA. As a result, investors believe that these asset-based securities carry the same level of risk as the underlying asset, and that asset-based securities are clearly at higher risk than the underlying asset. Therefore, due to deregulation and globalization of financial markets, the 2008 financial crisis exposed the world. Basel III was developed in response to the shortcomings of financial supervision after the 2008 financial crisis. Increase capital requirements by increasing bank liquidity and reducing bank leverage. The agreement was reached at the Basel Communiqué in November 2010 and is scheduled to begin in 2013-2015. However, implementation has been repeatedly postponed until the end of March 2019.

According to Basel III, the rule requires banks to raise funds at 4.5% of common stock in risk-weighted assets, and banks must maintain this level in 2015. The calculation method for this ratio is as follows:

$$\text{Conmonequitytier1(CET1)ratio} = \frac{\text{CET1}}{\text{RWA}_s} \geq 4. \tag{3.28}$$

In addition, the Tier 1 ratio has increased from 4% for Basel II to 6% and should be applied in 2015. Tier 1 ratios include common stock Tier 1 ratios and other Tier 1 ratios, accounting for 1.5%. In addition, Basel III has introduced two additional capital buffers. One is the essential capital saving buffer. This is equivalent to 2.5% of RWA. Given that CET1 has a capital adequacy ratio of 4.5%, banks must maintain a total buffer capital adequacy ratio of 7%. Another capital buffer is any countercyclical buffer. This allows national regulators to demand up to 2.5% additional capital during periods of significant credit growth. The level of this buffer zone is between 0% and 2.5% of RWA and must be met by CET1 capital. A summary of Basel III phased implementation arrangements, as shown in *Tab 3.12*.

Tab. 3.12 Basel III phase-in arrangements (%)

	Phases	2013	2014	2015	2016	2017	2018	2019
Capital	Leverage ratio			a			b	
	Minimum common equity capital ratio	3.5	4.0	4.5				4.5
	Capital conservation buffer				0.625	1.25	1.875	2.50
	Minimum common equity plus capital conservation buffer	3.5	4.0	7.5	5.125	5.75	6.375	7.0
	Phase-in of deductions from CET1	20		40	60	80	100	100
	Minimum Tier 1 capital	4.5	5.5	6.0				6.0
	Minimum total capital	8.0						8.0
	Minimum total capital plus conservation buffer	8.0			8.625	9.25	9.875	10.5
	Capital instruments that no longer qualify as non-core Tier1 capital orTier2 capital	Phased out over 10-year horizon beginning 2013						
Liquidity	Liquidity coverage ratio - minimum requirement			60	70	80	90	100
	Net stable funding ratio							

Source: BIS.

Overall, the six main provisions of Basel III are:

The minimum level of core Tier 1 capital adequacy ratio should always be maintained at 4.5%. Maintaining a buffer to prevent economic and financial pressure requires 2.5% of capital. This means that the minimum level of total capital should always be maintained at 13%.The minimum level of total capital must always be 8%. Level 1 leverage ratio is 3%. Two liquidity ratios, the Liquidity Coverage Ratio (LCR) and the Net Stable Funding Ratio (NSFR), have been added to help banks withstand liquidity pressures. The market value of counterparty credit risk and the risk weight of mortgage exposure are 1% to 3%.

4. Determination of Credit Risk by Selected Model

In this chapter, we will practice the theories we talk in the last chapter for a better understanding. The capital adequacy required for expected losses caused by credit risk is calculated according to the Basel Accords model and the CreditMetrics™ model, respectively.

First, we will discuss input data and investment portfolio. 10 companies were selected. Then, according to the Basel Accords, the size of the regulated capital is calculated using the standard method (SA) and the method based on the Foundation's internal rating-based apporach(FIRB). In addition, the calculation of economic capital based on the CreditMetrics™ model will be introduced. Finally, conclusions are drawn and comparisons are made.

4.1 Input data

The portfolio selected here includes 10 different fixed income transactions on the Frankfurt Stock Exchange, and its debtors are also listed. To diversify, the debtors we choose have different credit ratings and belong to different industries. In this case, assuming the total face value of the portfolio is 10 million Euros, the average face value of each bond will be 1 million euros to avoid the different face value biases of the different bonds. All information can be found on the official website of the Frankfurt Stock Exchange. The date this data was collected is March 29, 2021.

Important information mainly includes face value, coupon size, maturity date, market price, grade, and seniority. All bonds are well-known corporate bonds and do not need to cover mortgages, so unsecured priority is prioritized. See *Tab 4.1* below for basic information on these bonds.

Tab 4.1: Basic information about individual bonds

Name	Rating	Coupon	Nominal value	Maturity	Market price	pcs.
NIKE	AA-	2.85%	2000	03/2030	104.32%	500
General Electric	BBB+	4.13%	1000	09/2029	133.40%	1000
Daimler AG	BBB+	1.13%	1000	08/2028	100.62%	1000
Tencent	A+	3.80%	200000	02/2025	107.95%	5
BMW	A+	2.38%	1000	01/2023	104.71%	1000
Deutsche Wohnen SE	A-	1.68%	1000	08/2028	99.50%	1000
Deutsche Telekom AG	BBB	2.25%	10000	07/2023	102.30%	100
Oracle Corp.	A	1.65%	2000	03/2026	100.28%	500
Deutsche Bank	BBB+	2.75%	1000	02/2025	104.95%	1000
Sanofi	AA	0.63%	100000	04/2024	102.53%	10

Source: Frankfurt Stock Exchange (FSE).

As shown on the *Tab 4.1*, Standard & Poor's (S & P) evaluated 10 debtors of different grades. The highest rated debtor is Sanofi (AA) and the lowest rated debtor is Deutsche Telekom AG (BBB). These bonds are denominated in euros and have a face value ranging from € 1,000 to € 200,000 and are different parts of each bond in the portfolio.

Since each bond has a different credit rating, it is also important to find a different default rate for each premium unsecured category credit rating. Specific default levels for different levels are displayed as *Tab. 4.2* below.

Tab. 4.2 The probability of default for different rating

Rating	PD	Rating	PD
AAA	0.00%	**BBB-**	0.27%
AA+	0.00%	**BB+**	0.71%
AA	0.00%	**BB**	1.26%
AA-	0.00%	**BB-**	4.19%
A+	0.01%	**B+**	8.85%
A	0.11%	**B**	24.42%
A-	0.20%	**B-**	48.62%
BBB+	0.20%	**CCC**	
BBB	0.27%		

The recovery rate by tab is 51.13%. according to *Tab. 3.2* from Carty & Lieberman in Chapter 3 due to that each bond is Senior Unsecured category with a standard deviation of 25.45%. Therefore, you can calculate the loss with the default value of 48.87% according to equation (2.1). In addition, the migration matrix is listed in Appendix 2. The migration matrix is from Standard & Poor.

4.2 Calculation of credit risk by CreditMetrics™

In this chapter, we will use the CreditMetrics™ model to estimate economic capital. According to the model description, this process involves four main steps. First, we need to estimate the correlation of each debtor by generating a series of stock prices for one year. The present value of each bond in each rating category is then estimated by discounting the rate of return on futures. The forward yield curve for each possibility level can be represented by a possibility transition matrix. The Monte Carlo stimulus then generates a random yield of 25,000 per bond. This is a way to understand the value of portfolio. Finally, calculate the result with some confidence and express it as economic capital.

4.2.1 Estimation of the correlation among bonds issuers

Focus on the market price of each debtor's stock to estimate the correlation between bond issuers. To avoid deviations, select a one-year period for the stock price on each trading day, from March 30, 2020 to March 29, 2021. *Tab 4.3* shows the correlation matrix of 10 obligors is listed. The calculations are based on the stock prices of each FSE company and are listed in Appendix 3

Tab. 4.3 Correlations among individual issuers

	NIKE	GE	DAI.DE	TCEHY	BMW	DWNI.DE	DTEGY	ORCL	DB	SNY
NIKE	1.00	0.33	-0.01	0.31	-0.02	0.00	0.37	0.28	0.38	0.26
GE	0.33	1.00	-0.05	0.05	-0.10	-0.03	0.37	0.26	0.61	0.12
DAI.DE	-0.01	-0.05	1.00	-0.04	-0.03	0.04	-0.07	-0.03	-0.10	0.10
TCEHY	0.31	0.05	-0.04	1.00	0.01	0.04	0.11	0.14	0.12	0.24
BMW	-0.02	-0.10	-0.03	0.01	1.00	0.05	0.08	0.04	-0.05	0.08
DWNI.DE	0.00	-0.03	0.04	0.04	0.05	1.00	0.01	0.03	0.06	0.04
DTEGY	0.37	0.37	-0.07	0.11	0.08	0.01	1.00	0.35	0.57	0.33
ORCL	0.28	0.26	-0.03	0.14	0.04	0.03	0.35	1.00	0.29	0.17
DB	0.38	0.61	-0.10	0.12	-0.05	0.06	0.57	0.29	1.00	0.20
SNY	0.26	0.12	0.10	0.24	0.08	0.04	0.33	0.17	0.20	1.00

MS Excel Analysis Data / Data Analysis allows you to get the covariance matrix in Appendix 3 from each stock price, as well as the correlation matrix shown in *Tab 4.3* above. Both of the two matrices show some relationships between each pair of bonds. As explained earlier, the selected debtors are expected to be in different industries, so to provide this information, the correlation between each pair of bonds is very low. As an example of Nike and DWNI.DE, whose correlation is zero, one is real estate corporate and another one focuses on sporting goods production which is a less related industry with another. Moreover, the portfolio is not perfect diversified because several pair of issuers shows much higher correlation which is higher than 0.5 from matrix due to two issuers operate in two highly related industries. For example, the correlation of Deutsche Telekom AG and Deutsche Bank is 0.57.

4.2.2 Calculation of the value of bonds

Next, determining the present value of the selected bond You must then determine the present value of the selected bond. To get the current value, you need to derive the yield curve. Therefore, it is important to develop a multi-year transition matrix to understand risk-free interest rates, default probabilities, and recovery rates. By squaring the expected indicators, the multi-year migration matrix can be obtained from the annual migration matrix in Appendix 1. These multi-year transition matrices are listed in Appendix 4. The default probabilities are always the last column in the migration matrix for each multi-year. According to Carty and Lieberman's choice, the recovery rate was 51.13%. There is a need to get the current value, you need to derive the yield curve. Therefore, it is important to develop a multi-year transition matrix to understand risk-free interest rates, default probabilities, and recovery rates. By squaring the expected indicators, the multi-year migration matrix can be obtained from the annual migration matrix in Appendix 1. These multi-year transition matrices are listed in Appendix 4. The default probabilities are always the last column in the migration matrix for each multi-year. According to Carty and Lieberman's choice, the recovery rate was 51.13%. The risk-free asset we use is the Euro Interest Rate Swap from 2021 to 2030, interest rate swaps can be found on the official website of the Deutsche Bundesbank. Next, calculate the futures discount rate within 10 years according to Equation (3.12), and the results are shown in the following *Tab. 4.4.*

Tab 4.4 Spot rate (IRS) and forward rates from 2016 to 2025 (%)

Year	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
IRS	-0.16	-0.18	-0.12	-0.03	0.08	0.2	0.32	0.45	0.56	0.68
fn	-0.16	-0.19	-0.01	0.23	0.51	0.82	1.02	1.38	1.49	1.69

Source: Deutsche Bundesbank

Now, we may default within ten years and have a forward discount rate. Using the recovery rate, we can apply a discount rate for each rating category within ten years. See Annex 5 for the results of the forward discount rate.

Tab. 4.5 Present values of bonds according to the rating categories (€)

Bond	NIKE	GE	DAI.DE	TCEHY	BMW	DWNI.DE	DTEGY	ORCL	DB	SNY
AAA	2,241	1,243	991	233,539	1,071	1,137	10,669	2,108	1,115	101,277
AA+	2,240	1,243	991	233,512	1,071	1,137	10,669	2,108	1,115	101,269
AA	2,240	1,243	991	233,512	1,071	1,137	10,669	2,108	1,115	101,269
AA-	2,240	1,243	990	233,480	1,071	1,137	10,668	2,107	1,115	101,259
A+	2,238	1,242	990	233,400	1,070	1,137	10,666	2,106	1,115	101,230
A	2,232	1,239	987	232,981	1,069	1,137	10,651	2,102	1,113	101,062
A-	2,232	1,239	987	233,076	1,069	1,137	10,657	2,103	1,113	101,111
BBB+	2,224	1,235	984	232,611	1,068	1,137	10,643	2,098	1,111	100,937
BBB	2,218	1,232	982	232,215	1,067	1,137	10,632	2,093	1,109	100,792
BBB-	2,205	1,225	976	231,170	1,063	1,137	10,594	2,083	1,104	100,371
BB+	2,204	1,225	976	231,399	1,065	1,137	10,613	2,084	1,105	100,508
BB	2,179	1,211	965	229,164	1,057	1,137	10,528	2,062	1,094	99,592
BB-	2,109	1,174	935	223,872	1,039	1,137	10,354	2,007	1,069	97,535
B+	2,069	1,152	916	219,713	1,024	1,137	10,199	1,968	1,049	95,801
B	1,980	1,102	876	210,184	983	1,137	9,796	1,880	1,003	91,689
B-	1,695	945	748	181,086	861	1,137	8,576	1,610	863	79,199
CCC	1,370	762	605	144,811	678	1,137	6,756	1,295	691	63,056

Tab. 4.5 summarizes all the present value of each bond that has transitioned from default to each rating category. The higher the final rating, the higher the present value. The cells highlighted in red represent the present value of each bond that has transitioned from its default value to the grade currently assigned.

4.2.3 Simulation of value of portfolio

Next, perform Monte Carlo stimulation. Monte Carlo simulations need to generate a series of random returns. This can be achieved using the MS Excel feature Data / Data Analysis / Random Number Generator. Apply the standard normal distribution N (0,1) to generate these 25,000 random returns for each bonds. The whole scenarios can be found in Annex 6.

Since each issuer is independent, these dependencies need to be considered when simulating the rate of return. This can be achieved using the upper triangular Cholesky decomposition matrix shown in *Tab 4.6.*

Tab. 4.6 Cholesky decomposition matrix

	NIKE	GE	DAI.DE	TCEHY	BMW	DWNI.DE	DTEGY	ORCL	DB	SNY
NIKE	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
GE	0.33	0.86	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
DAI.DE	-0.01	0.25	0.76	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TCEHY	0.32	0.27	0.16	0.84	0.00	0.00	0.00	0.00	0.00	0.00
BMW	-0.02	0.02	0.06	-0.09	0.93	0.00	0.00	0.00	0.00	0.00
DWNI.DE	0.00	0.28	0.14	0.11	0.06	0.78	0.00	0.00	0.00	0.00
DTEGY	0.37	0.20	0.20	0.02	0.09	0.15	0.60	0.00	0.00	0.00
ORCL	0.29	0.17	0.27	0.04	0.18	0.05	0.18	0.74	0.00	0.00
DB	0.39	0.19	0.35	-0.06	0.07	-0.04	0.17	0.29	0.65	0.00
SNY	0.26	0.02	0.03	0.08	0.04	-0.18	0.09	0.12	0.08	0.95

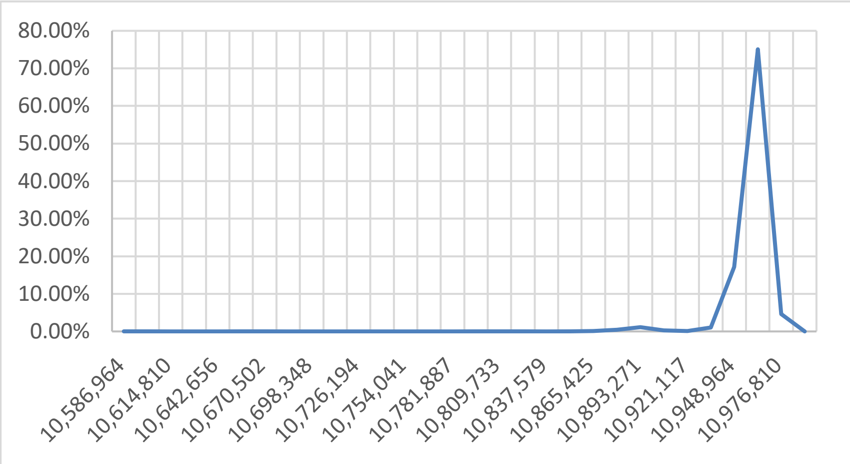
The Cholesky decomposition matrix can be obtained via the Cholesky decomposition calculator. When considering independence, you can multiply the matrix by a random return to get the associated random variables. The results of the relevant random variables are given in Appendix 6.

Later, you can use the MS Excel IF function to associate the associated random variable with the credit rating, taking advantage of the conversion limits for each rating category. The results are shown in Appendix 9. The breakpoints of limits of migration can be found in Annex 8. In this case, you can get the bond value of each scheme based on the valuation assigned with the *Tab. 4.5*. You can then calculate the total portfolio by multiplying the bond value of each situation by the number of bond portfolios you have and adding the total amount of each bond in the situation. Annex 10 shows the value of each bond and the total value of the portfolio of 25,000 scenarios.

4.2.4 Calculation of credit risk

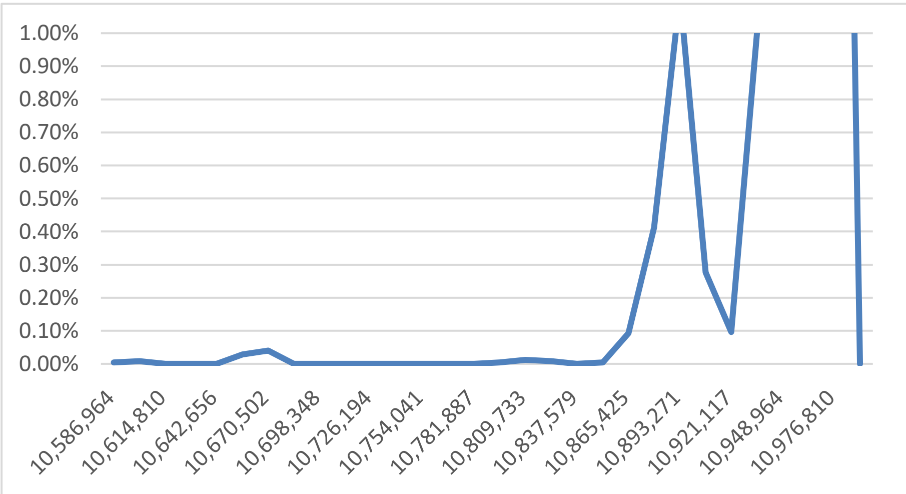
Finally, we try to estimate the economic capital of the portfolio. The values in the portfolio of the 25,000 scheme can be split into 30 equal parts, and the FREQUENCY function in MS Excel can be used to perform a probability distribution with equal and equal frequency. *Fig 4.1* below shows the probability distribution of portfolio values. In this way, you can also get the probability distribution of the default values in Appendix 10.

Fig 4.1: Probability distribution of the portfolio values



As shown in *Fig 4.1*, we can see that there is a left bias probability distribution with a long tail extending in the negative direction of the horizontal axis. This means that the distribution of credit risk is asymmetric. The value of the portfolio is most often displayed around € 10,962,887, and the value of the portfolio ranges from € 10,948,964 to € 10,962,887, accounting for 92.23% of the total area below the curve. Next, let's expand the number when the probability is 0% to 1%, as shown in *Fig. 4.2*.

Fig. 4.2: Probability distribution of the portfolio values – adjusted scale



We can see that only a few options have a relatively low portfolio value because the probability distribution is negatively distorted. This indicates that the probability is low. As an example of portfolio values ranging from € 10,600,887 to € 10,865,425, as shown in *Fig. 4.2* above, they account for about 0.2% of all portfolio values, significantly lower than the probability of the most frequent trading range. doing. In addition, the lowest possible portfolio value is € 10,586,964.

Then calculate the expected loss for each bond and portfolio. Currently, we know the initial value of each bond and the average value of each bond in 25,000 scenarios. The expected loss is the difference between the two parameters and the result can be displayed as a *Tab. 4.7.*

Tab. 4.7: Results of the portfolio value (€)

Bond	Values	Mean value	Expected lost
NIKE	1119754	1118542	1212
GE	1235114	1234830	284
DAI.DE	984405	984433	-28
TCEHY	1167000	1166813	187
BMW	1070378	1070196	182
DWNI.DE	1136987	1136825	162
DTEGY	1063175	1064875	-1700
ORCL	1050994	1051162	-169
DB	1110990	1111066	-75
SNY	1012690	1012470	221
Portfolio	10951501	10951387	274

The initial market price of the portfolio is approximately € 10,951,501 and the expected value of the portfolio is € 10,951,387. The difference between the initial values of the expected value is 274 €, which represents the expected loss. In addition, expected loss accounts for 0.002% of the total portfolio, which may be due to a high bond rating. DTEGY caused the expected positive loss. This means that the company will face the expected profits. We then calculated the risk as a form of standard deviation and marginal risk for each bond. The results are summarized as *Tab.4.8.*

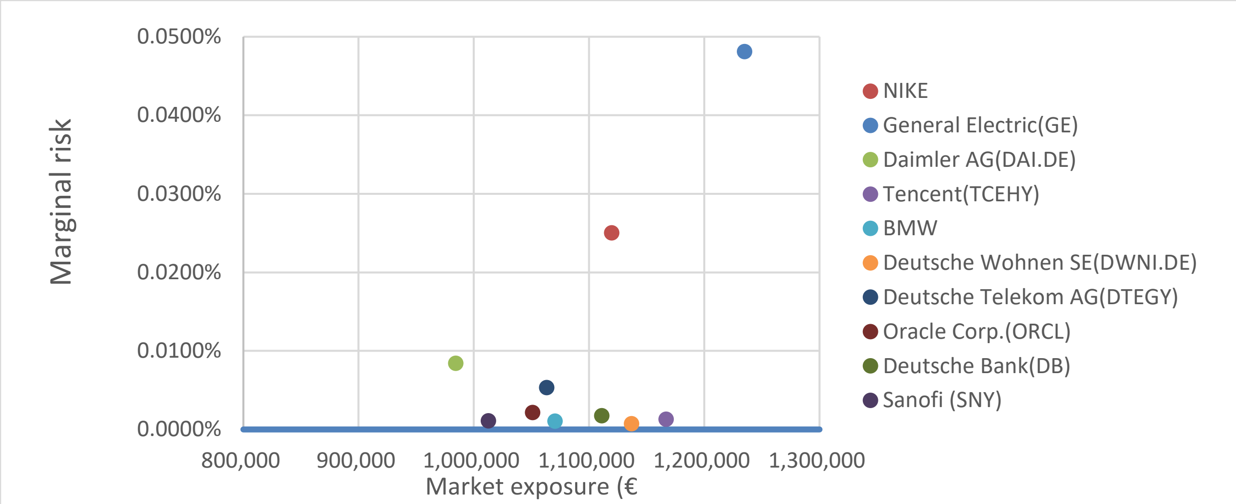
Tab. 4.8 Parameters of risk

	Standard deviation		**Marginal standard deviation**	
	%	**€**	**%**	**€**
NIKE	0.6542%	7,317	0.0250%	2,657
GE	0.8206%	10,133	0.0481%	5,101
DAI.DE	0.3629%	3,573	0.0084%	892
TCEHY	0.0615%	718	0.0013%	140
BMW	0.0534%	572	0.0011%	114
DWNI.DE	0.0269%	256	0.0007%	78
DTEGY	0.2242%	2,387	0.0053%	564
ORCL	0.0967%	1,017	0.0022%	230
DB	0.0758%	842	0.0018%	187
(SNY	0.0453%	459	0.0011%	115
Portfolio	**0.1624%**	**14,624**		

Focus on three high-expected debtors Nike, GE, and DAI.DE with relatively high credit risk and standard deviations of 0.65%, 0.82%, and 0.36%, respectively. The standard deviation of the portfolio is around 0.1624% and € 14,624, which is much lower than the sum of all bonds due to diversification.

Later, with the help of the ISO risk line, we will discuss the marginal risk of 10 bonds. The ISO risk line combines all points with the same absolute marginal risk. The results are shown in *Fig. 4.3* below.

Fig. 4.3 Marginal risk with ISO-risk line



Finally, we compare the value of different portfolios with different levels of value at risk. Three different significance levels are used here: 0.1%, 0.5%, and 1%. We can see that the results are displayed as *Tab. 4.9* below .

Tab 4.9: Percentiles and corresponding value of the portfolio and losses

alpha	Portfolio value	VaR
0.1%	9,906,663	-1,044,838
0.5%	10,862,287	-89,213
1%	10,878,240	-73,260

At a confidence level of 99.9%, the maximum VaRs faced are € 9,906,663 and € 1,044,838, minimizing the value of the portfolio. Obviously, changing the reliability level from 0.1% to 0.5% causes the VaR to drop sharply. Economic capital can then be calculated according to *Equation (3.1)* as a buffer against unexpected losses due to credit risk. The results are in the *Tab 4.10* below.

Tab. 4.10 Percentiles and corresponding economic capital

alpha	Economic capital
0.1%	132,299
0.5%	73,904
1%	68,058

At a 99.9% confidence level, the economic capital reaches 132,299 €. It is 73,904 € and 68,058 € at 99.5% and 99% confidence level, respectively. Moreover, the values of economic capitals change sharply even when the significance levels change slightly because of the effect of heavy ends typical for credit risk.

4.3 Calculation of credit risk under Basel I, II and III

Now, we can determine the size of the capital requirement through the method under the Basel Agreement to make up for unexpected losses caused by credit risk. Based on Basel I, II, and III, there are some different capital requirements to make up for unexpected losses caused by credit risk. The calculation method is described in chapter 3.4. Each bond in the portfolio is expressed with the same weight, which is equivalent to a face value of one million euros.

4.3.1 Under Basel I

Under Basel I, the estimation of capital requirements is based on *Equation (3.22)*. Capital requirements can be estimated by calculating RWA. The results of RWA and capital requirements are shown in the following table.

Tab. 4.11 Regulatory capital requirement under Basel I

Basel I	Rating	Nominal value	w	RWA	CR
NIKE	AA-	1,000,000	100%	1,000,000	80,000
General Electric	BBB+	1,000,000	100%	1,000,000	80,000
Daimler AG	BBB+	1,000,000	100%	1,000,000	80,000
Tencent	A+	1,000,000	100%	1,000,000	80,000
BMW	A+	1,000,000	100%	1,000,000	80,000
DeutscheWohnenSE	A-	1,000,000	100%	1,000,000	80,000
Deutsche Telekom AG	BBB	1,000,000	100%	1,000,000	80,000
Oracle Corp.	A	1,000,000	100%	1,000,000	80,000
Deutsche Bank	BBB+	1,000,000	20%	200,000	16,000
Sanofi	AA	1,000,000	100%	1,000,000	80,000
Total	-	-	-	9,200,000	736,000

The above results show that there is no consideration of the fundamental shortage of Basel I, the credit eligibility of the borrower. Therefore, since only one of the ten debtors is a bank and the others are companies, the assigned risk weight for banks other than German banks is 100%, and the risk weight for German banks is 20%. Therefore, the total value of risk-weighted assets is 9.2 million. In euros, the value of regulated capital requirements is 736,000 euros

4.3.2 Under Basel II

The calculation of capital requirements under Basel II is subject to each obligator's rating. Different ratings and industries have different risk weights. In addition, as explained in the previous chapter, there are several ways to calculate the required capital. Here we use the standard method and the method based on the Foundation's internal rating.

Tab. 4.12 Regulatory capital requirements under Basel II - SA

Basel II - SA	Rating	Nominal value	w	RWA	CR
NIKE	AA-	1,000,000	20%	200,000	16,000
General Electric	BBB+	1,000,000	100%	1,000,000	80,000
Daimler AG	BBB+	1,000,000	100%	1,000,000	80,000
Tencent	A+	1,000,000	50%	500,000	40,000
BMW	A+	1,000,000	50%	500,000	40,000
DeutscheWohnenSE	A-	1,000,000	50%	500,000	40,000
Deutsche Telekom AG	AA	1,000,000	20%	200,000	16,000
Oracle Corp.	A-	1,000,000	50%	500,000	40,000
Deutsche Bank	BBB+	1,000,000	100%	1,000,000	80,000
Sanofi	AA-	1,000,000	20%	200,000	16,000
Total	-	-	-	5,600,000	448,000

Credit ratings play an important role when assigning risk weights. In general, the higher the credit rating, the lower the risk weight. In this example, the risk weight varies from 20% to 100%. As an example of the debtor NIKE, the risk weight has been reduced from 100% under the Basel Accords to 20% under the Basel Accords.

In addition, due to the relatively low rating, Deutsche Bank's risk weight increased from 20% to 100%. The difference between Basel I and Basel II risk-weighted assets is € 3.6 million. The capital requirement to take credit risk according to Basel II's standard method was € 448,000, which decreased from € 736,000 to € 448,000, a decrease of approximately 39.13%. As a result of considering the obligator's rating, we can see that this number has dropped significantly.

In addition, the size of capital can be determined by the foundation internal ratings-based approach under the Basel II. The results are shown in *Tab. 4.13*.

Tab. 4.13 Regulatory capital requirements under Basel II - FIRB

Basel II - FIRB	**CR**	**RWA**
NIKE	4,179	52,235
GE	38,600	482,497
DAI.DE	38,600	482,497
Tencent	8,025	100,317
BMW	8,025	100,317
DWNI.DE	38,343	479,283
DTEGY	3,145	39,314
Oracle Corp.	38,343	479,283
Deutsche Bank	38,600	482,497
Sanofi	4,179	52,235
Total	220,038	2,750,474

Using FIRB approach, banks can use internal empirical models to estimate three parameters (PD, LGD, and EAD) to further influence capital requirements. Therefore, if the debtor's default probability is low, the risk weight is significantly reduced. Compared to the standard method, you can see that both RWA and capital requirements have been significantly reduced. In the FIRB approach, the lower the probability of default, the less capital is needed to cover the risk. In addition, RWA has been reduced from € 5.6 million to approximately 2.75 million and the capital requirements of various methods have been reduced from € 448,000 to € 220,038, almost 50.8% reduction. This is due to the sharp decline in RWA and the capital adequacy required for each bond.

4.3.3Under Basel III

Third, the size of capital requirements is determined according to Basel III, including standard methods and methods based on the Foundation's internal rating based on Basel II. The calculation process based on the standard method is the same as in Basel II, but in Basel III the minimum level of capital adequacy ratio is 13%, 10.5% plus 2.5% countercyclical buffer. Therefore, it is necessary to calculate the minimum capital requirement level without a countercyclical buffer. The results are shown in *Tab. 4.14*.

Tab. 4.14 Regulatory capital requirements under Basel III – SA

Basel III - SA	Rating	Nominal value	w	RWA	CR
NIKE	AA-	1,000,000	20%	200,000	21,000
General Electric	BBB+	1,000,000	100%	1,000,000	105,000
Daimler AG	BBB+	1,000,000	100%	1,000,000	105,000
Tencent	A+	1,000,000	50%	500,000	52,500
BMW	A+	1,000,000	50%	500,000	52,500
DeutscheWohnenSE	A-	1,000,000	50%	500,000	52,500
Deutsche Telekom AG	AA	1,000,000	20%	200,000	21,000
Oracle Corp.	A-	1,000,000	50%	500,000	52,500
Deutsche Bank	BBB+	1,000,000	100%	1,000,000	105,000
Sanofi	AA-	1,000,000	20%	200,000	21,000
Total	-	-	-	5,600,000	588,000

From the results shown in *Tab 4.6* above, it is clear that the total value of risk-weighted assets in Basel III-SA is the same as the total value of risk-weighted assets in Basel II-SA. However, as the minimum capital requirement increased by 2.5%, the value of the capital requirement increased from € 448,000 to € 588,000, the difference is 140,000 € which can be considered as conservation buffer. On the other hand, compared to Basel I results, total risk-weighted assets and capital requirements decreased by 39.13% and 20.1%, respectively.

Then use the FIRB approach to estimate the size of the required capital. The process is similar to Basel II, but the minimum capital adequacy ratio has been changed from 8% to 10.5%. The summary results are shown in *Tab. 4.15* below.

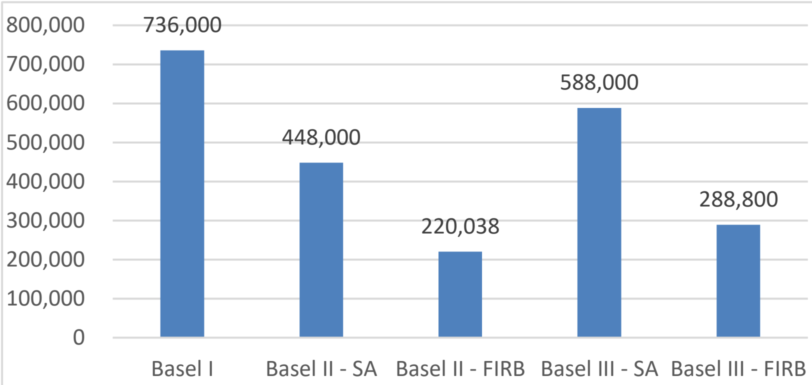
Tab. 4.15 Regulatory capital requirement under Basel III – FIRB

Basel III - FIRB	CR	RWA
NIKE	5,485 €	68,558 €
General Electric	50,662 €	633,277 €
Daimler AG	50,662 €	633,277 €
Tencent	10,533 €	131,666 €
BMW	10,533 €	131,666 €
DeutscheWohnenSE	50,325 €	629,058 €
DeutscheTelekom AG	4,128 €	51,600 €
Oracle Corp.	50,325 €	629,058 €
Deutsche Bank	50,662 €	633,277 €
Sanofi	5,485 €	68,558 €
Total	288,800 €	3,609,997 €

Comparing the results of the Basel III FIRB method with the results of the Basel II FIRB apporach, we can see that both RWA and CR are increased. The absolute changes and capital requirements for RWA are € 859,523 and € 68,762, respectively. This change is mainly due to a change in the minimum capital adequacy ratio. Comparing the results of the FIRB apporach with the results of the Basel III standard method, the required capital was reduced from € 588,000 to € 288,800. The absolute change is € 299,200 and the percentage change is about 50.8%.

In summary, all the calculated capital requirements for each method under different contracts are shown in *Fig. 4.4* below.

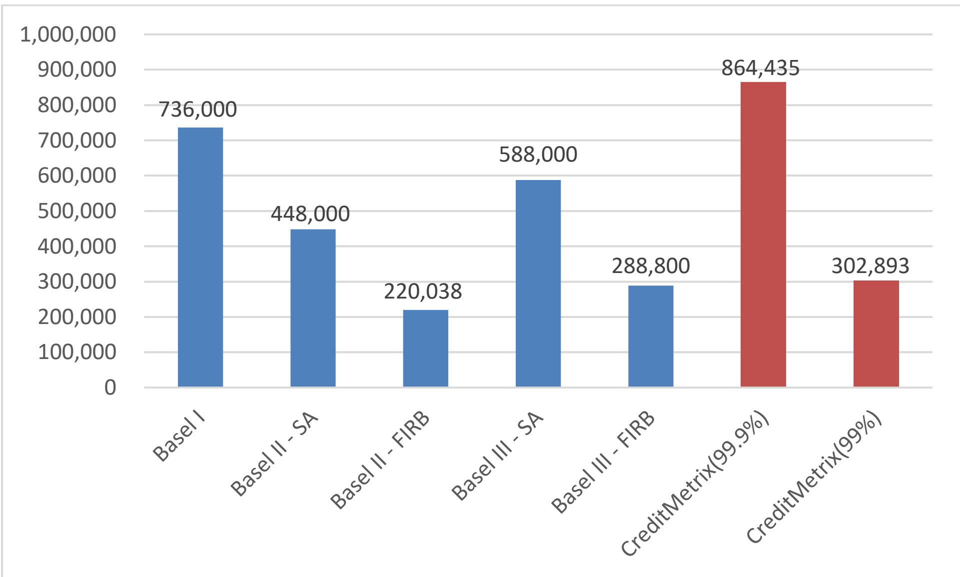
Fig. 4.4 Regulatory capital requirement under Basel I, II and III



4.4 Evaluation of results

In chapter 4.2 we use the CreditMetrics™ model to calculate economic capital by generating 25,000 random variables at various confidence levels. Then, under the three versions of the Basel Accords in Chapter 4.3, we calculated the required capital in various ways. The main idea of economic capital and capital demand is to make up for unexpected losses, so at the end of this chapter we will summarize the results of each method. The results are shown in *Fig. 4.5* below.

Fig. 4.5 Regulatory capital requirments under different methods



The main goals of calculating capital requirements under the Basel Accords and calculating economic capital under the CreditMetrics^{TM} model are about the same, to compensate for unexpected losses. In other words, we can compare the results of these two methods. As mentioned earlier, the standard method has a higher return on capital because the same method is used to estimate the unexpected losses for large and small businesses. Therefore, the investment portfolio, the foundation IRB method, is more important when both companies and SMEs exist.

As shown in *Fig. 4.5*, the CreditMetrics^{TM} model has an economic capital value of € 864,435 with a confidence level of 99.9%, which is much higher than the capital requirements of the Basel III standard law. However, the economic capital result of € 302,893 at the 99% confidence level is similar to the result of the capital requirement using Basel III's basic IRB method.

Diversification is the main reason to explain the different values estimated by the two models. As mentioned in the previous chapter, the CreditMetrics^{TM} model needs to consider the correlation of different obligators in the portfolio. The higher the degree of the correlation, the higher the level of the regulatory capital requirement. Relevance must also be considered when calculating regulatory capital requirements in the form of default probabilities under the Basel Accords. There is a significant difference between the two related measurements examined by these two methods. In the CreditMetrics^{TM} model, *Tab.4.3* shows the correlation matrix calculated from the actual stock price. The range is -10% to 61%. However, the correlation (R) considered in the foundation IRB approach is calculated based on the default probability and can be seen in Appendix 13, which varies from 23% to 24% (narrow intervals). If the correlations used in the foundation IRB approach are considered highly independent, then a portfolio containing 10 bonds cannot be fully diversified, resulting in a wide range of correlations.

5. Conclusion

Nowadays, the importance of financial risks, especially credit risks, is receiving more and more attention. Especially the 2008 global financial crisis. This is mainly due to the structural changes in economics, that is, the increase in the degree of globalization of the world's financial markets. Credit risk refers to the potential loss that a financial institution may cause when the borrower fails to perform its obligations. Therefore, it is important to effectively measure and manage credit risk.

The main purpose of this thesis is to estimate the economic capital of ten selected bond portfolios based on the CreditMetrics^{TM} model, and to estimate the capital required for unexpected losses caused by the credit risk of the Basel Agreement. It provides a possible way to compare the results of the Basel Agreement (including Basel I, Basel II and Basel III) and the CreditMetrics^{TM} model.

The full thesis is divided into five chapters. Chapter 2 and Chapter 3 constitute the theoretical part. The practical part can be found in Chapter 4. Chapter 5 is based on the summary and conclusion of the results.

The theoretical part mainly focuses on different types of financial risks, followed by credit risk management and model descriptions. Give some examples and describe financial risks in detail, including credit risk, market risk, operational risk and liquidity risk. Finally, people discussed different versions of the Basel Agreement on capital adequacy ratios.

In the practical part, an example of a portfolio of ten selected bonds traded on the Frankfurt Stock Exchange was used as economic capital using the CreditMetrics^{TM} model. In addition, according to different versions of the Basel Agreement, different methods have been used to estimate the capital required to make up for unexpected losses. The notional value of the entire portfolio is 10 million Euros, and we have chosen a term of one year. Then, we will conduct a special analysis and comparison of all the results.

One of the goals of the implementers of the Basel Agreement is to bring regulatory capital requirements as close as possible to economic capital. The results obtained in Chapter 4 show that it is calculated in Basel II according to standard methods. In addition, the confidence level of economic capital is 99, which is equal to 302,893 euros, which is very close to the regulatory capital requirements calculated based on the basic rating methods of Basel II and Basel III. If the investment portfolio is not diversified enough, one of the possible reasons is that the degree of correlation in the different methods is different. Specifically, when the basic method based on internal ratings is used in both Basel II and Basel III, the correlation depends on the probability of default, ranging from 23% to 24%. In contrast, when using the CreditMetrics™ model, the correlation range shown in the correlation matrix is -10% to 61%.

With the changes in the world, the credit risk management process is constantly improving. With the advancement of technology and the improvement of advanced levels, customers' expectations of financial institutions are also constantly increasing. Given that highly complex financial instruments ultimately depend on the responsibility of each investor, it is important to build a fully diversified investment portfolio. Moreover, if there are more versions of the Basel Agreement, regulatory capital requirements will be increasingly restricted.

Bibliography

Professional books

[1] AMMANN, M.: *Credit Risk Valuation: Methods, Models and Applications*. 2nd ed. Berlin: Springer, 2001. 255 p. ISBN 3-540-67805-0.

[2] ANDREA, S. and ANDREA, R. *Risk Management and Shareholders' Value in Banking: From Risk Measurement Models to Capital Allocation Policies*. Wiley Finance, 2007. ISBN 978-0-0470-02978-7.

[3] APOSTOLIK, R., CH. DONOHUE, and P. WENT. *Foundations of Banking Risk: An Overview of Banking, Banking Risks, and Risk-Based Banking Regulation*. Wiley Finance, 2009. ISBN 978-0-470-44219-7.

[4] BASEL COMMITTEE ON BANKING SUPERVISION: *Basel III framework for liquidity – Frequently asked questions,* Basel, July 2011 22 p ISBN 92-9197-875-2.

[5] BASEL COMMITTEE ON BANKING SUPERVISION: *Basel III: A global regulatory framework for more resilient banks and banking,* Basel, June 2011 77 p. ISBN: 92-9197- 859-0.

[6] BASEL COMMITTEE ON BANKING SUPERVISION: *International Convergence of Capital Measurement and Capital Standards,,* Basel, June 2006. 347 p. ISBN: 92-9197- 720-9.

[7] BESSIS, J.: *Risk Management in Banking,* Chichester: John Wiley & Sons Ltd, 2003. 792 p. ISBN 0-471-89336-6.

[8] CASU, B., GIRARDONE, C., and MOLYNEUX, P. *Introduction to Banking*. Pearson Education Limited, 2006. ISBN 978-0-273-69302-4.

[9] CUPTON, G. M., C. C., FINGER, and M., BHATIA. *CreditMetrics Technical Document*. New York: J. P. Morgan, 1997.

[10] FELSENHEIMER, Jochen, Philip GISDAKIS, and Michael ZAISER. *Active Credit Portfolio Management: A Practical Guide to Credit Risk Management Strategies*. Wiley Finance, 2006. ISBN 3-527-50198-3.

[11] JOHN C. HULL. *Risk Management and Financial Institutions*. 4th ed. Wiley Finance, 2015. ISBN 978-1-118-95594-9.

[12] ROSE, P. and S. HUDGINS. *Bank Management and Financial Services*. 9th ed. McGraw- Hill/Irwin, 2012. ISBN 978-0078034671.

Electronic documents and others

[13] Cholesky decomposition calculator [online]. [22. 03. 2021]. Available on: https://www.atozmath.com/MatrixEv.aspx?q=choleskydecomp

[14] Deutsche Bundesbank. *Euro Swap* [online]. BB [29. 03. 2021] Available on: https://www.bundesbank.de/de

[15] Frankfurt Stock Exchange. Bonds [online]. FSE [12. 03. 2021]. Available on: http://en.boerse-frankfurt.de/

[16] STANDARD & POOR'S RATINGA SERVICES. *Default, Transition, and Recovery: 2014 Annual Global Corporate Default Study and Rating Transitions* [online]. Standard & Poor's [20. 3. 2021]. Available on: https://www.nact.org/resources/2014_SP_Global_Corporate_Default_Study.pdf.

[17] STANDARD & POOR'S RATINGA SERVICES. Rating [online]. Standard & Poor's [29. 3. 2021]. Available on: https://www.standardandpoors.com/en_US/web/guest/home.

[18] YAHOO FINANCE. Stock prices [online]. YF [28. 03. 2021]. Available on: https://finance.yahoo.com/

List of Abbreviations

ACB	Agricultural Bank of China
BCBS	Basel Committee for Banking Supervision
BIS	Bank for Internationla Settlements
CIRC	China Insurance Regulatory Committee
CR	Capital requirement
CRAs	Credit rating agencies
DD	Distance of default
EAD	Exposure at default
EL	Expected loss
EURINOR	Euro InterBank Offered Rate
FSE	Frankfurt Stock Exchange
IRS	Interest rate swap
LCR	Liquidity coverage ratio
LIBOR	London InterBnak Offered Rate
LGD	Loss given default
LLA	Loan loss allowance
LTD	Long-term debt
NPL	Nonperforming loans
NSFR	Net stable funding ratio
OECD	Organization for Economic Co-operation and Development
PD	probability of default
PRIBOR	Prague InterBank Offered Rate
RR	Recovery rate
RWA	Risk-weighted asset
STD	Shord-term debt
UL	Uxpected loss
VaR	Value at Risk

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List of Annexes

Annexes

Annex 1 Risk weights by category of on-balance-sheet asset

0%	a) Cash b) Claims on central governments and central banks denominated in national currency and funded in that currency c) Other claims on OECD central governments and central banks d) Claims collateralized by cash of OECD central-government securities or guaranteed by OECD central government
20%	a) Claims on multilateral development banks (IBRD, IADB, AsDB, AfDB, EIB) and claims guaranteed by, or collateralized by securities issued by such banks b) Claims on banks incorporated in the OECD and loans guaranteed by OECD incorporated banks c) Claims on banks incorporated in countries outside the OECD with a residual maturity of up to one year and loans with a residual maturity of up to one year guaranteed by banks incorporated in countries outside the OECD d) Claims on non-domestic OECD public-sector entities, excluding central government, and loans guaranteed by such entities e) Cash items in process of collection
50%	a) Loans fully secured by mortgage on residential property that is or will be occupied by the borrower or that is rented
100%	a) Claims on the private sector b) Claims on banks incorporated outside the OECD with a residual maturity of over one year c) Claims on central governments outside the OECD (unless denominated in national currency - and funded in that currency) d) Claims on commercial companies owned by the public sector e) Premises, plant and equipment and other fixed assets f) Real estate and other investments (including non-consolidated investment participations in other companies) g) Capital instruments issued by other banks (unless deducted from capital) h) all other assets

Annex 2: Probability matrix from Standard & Poor's

	AAA	AA+	AA	AA-	A+	A	A-	BBB+	BBB	BBB-	BB+	BB	BB-	B+	B	B-	CCC	D
AAA	85.03%	6.72%	1.52%	0.87%	0.22%	0.43%	0.00%	0.00%	0.22%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
AA+	1.09%	74.86%	15.03%	2.73%	0.82%	0.82%	0.55%	0.55%	0.00%	0.27%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
AA	0.22%	1.20%	78.98%	8.50%	4.14%	1.31%	0.54%	0.22%	0.00%	0.11%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
AA-	0.08%	0.08%	4.56%	74.98%	12.26%	2.73%	1.24%	0.17%	0.08%	0.17%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
A+	0.00%	0.07%	0.63%	5.51%	73.97%	10.89%	2.58%	0.49%	0.35%	0.07%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
A	0.00%	0.23%	0.17%	0.74%	4.69%	73.46%	11.21%	2.29%	1.14%	0.17%	0.06%	0.06%	0.06%	0.06%	0.00%	0.00%	0.00%	0.11%
A-	0.05%	0.00%	0.16%	0.16%	0.98%	7.22%	76.11%	7.93%	1.48%	0.82%	0.16%	0.05%	0.11%	0.00%	0.00%	0.00%	0.00%	0.05%
BBB+	0.00%	0.00%	0.00%	0.14%	0.29%	0.86%	7.43%	73.50%	8.71%	1.21%	0.36%	0.57%	0.21%	0.21%	0.07%	0.00%	0.14%	0.07%
BBB	0.00%	0.00%	0.10%	0.00%	0.19%	0.58%	0.88%	7.89%	69.98%	7.89%	1.66%	1.07%	0.10%	0.10%	0.39%	0.10%	0.10%	0.10%
BBB-	0.00%	0.00%	0.16%	0.00%	0.16%	0.64%	0.48%	1.43%	8.90%	67.25%	6.52%	2.70%	0.79%	0.32%	0.32%	0.00%	0.32%	0.32%
BB+	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.30%	0.60%	0.90%	11.64%	58.81%	8.06%	2.39%	1.79%	0.30%	0.00%	0.30%	0.00%
BB	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.25%	0.50%	0.00%	1.75%	11.25%	56.75%	6.25%	2.75%	1.00%	0.00%	0.75%	0.50%
BB-	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.25%	0.25%	0.25%	8.89%	59.01%	12.84%	4.20%	0.49%	0.25%	1.48%
B+	0.00%	0.00%	0.00%	0.00%	0.00%	0.23%	0.00%	0.23%	0.00%	0.00%	0.23%	2.93%	8.80%	54.63%	8.35%	3.84%	1.35%	1.81%
B	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.38%	0.38%	0.38%	1.51%	12.08%	45.66%	8.30%	4.53%	4.15%
B-	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.63%	0.00%	0.00%	0.00%	0.00%	1.27%	6.33%	49.37%	15.82%	10.13%
CCC	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	1.15%	3.46%	9.20%	25.29%	37.93%

Annex 3: Shares prices from March 30th, 2020 to March 29th, 2021 (€)

Date	NIKE	GE	DAI.DE	TCEHY	BMW	DWNI.DE	DTEGY	Oracle	DB	SNY
2020/3/30	85.38	7.89	27.52	49.64	44.38	34.57	13.21	50.36	6.51	44.69
2020/3/31	82.74	7.94	25.53	49.09	44.87	34.50	12.94	48.33	6.42	43.72
2020/4/1	79.23	7.04	25.17	47.06	44.75	35.02	12.51	48.71	5.96	42.91
2020/4/2	80.14	6.90	24.52	48.82	48.56	35.11	12.51	49.80	6.02	43.51
2020/4/3	78.86	6.73	27.34	47.81	49.72	34.84	12.50	49.40	5.90	44.83
2020/4/6	84.63	7.23	28.14	49.94	49.16	34.92	13.18	51.49	6.38	46.12
2020/4/7	84.16	7.03	28.13	49.47	50.82	35.05	13.39	50.76	6.64	44.60
2020/4/8	85.30	7.30	29.84	50.15	51.36	34.85	13.34	52.13	6.54	45.18
2020/4/9	86.79	7.14	29.40	49.47	48.59	35.09	13.56	53.18	6.69	45.46
2020/4/13	84.46	7.02	27.62	49.80	49.33	35.09	13.41	52.97	6.52	44.38
2020/4/14	87.47	6.93	27.69	51.45	51.91	35.50	13.66	54.00	6.85	45.97
2020/4/15	85.04	6.50	29.04	50.96	51.37	35.10	13.19	53.16	6.23	45.15
2020/4/16	86.30	6.24	28.67	53.11	48.56	35.11	13.18	53.70	6.22	46.13
2020/4/17	89.91	6.84	27.43	52.35	49.01	35.28	13.59	54.62	6.54	47.75
2020/4/20	87.90	6.51	27.85	52.46	50.27	36.97	13.61	53.91	6.33	48.28
2020/4/21	85.20	6.48	28.74	51.07	48.66	36.47	13.23	51.31	6.08	48.60
2020/4/22	88.77	6.43	27.56	52.86	51.20	36.68	13.57	52.27	6.09	48.19
2020/4/23	87.35	6.52	29.32	52.46	52.61	36.64	13.37	51.97	6.18	48.37
2020/4/24	88.37	6.26	30.41	52.85	55.67	36.73	13.64	53.01	5.95	49.85
2020/4/27	89.37	6.43	32.44	53.30	54.05	37.00	14.06	53.37	6.69	50.63
2020/5/7	88.56	6.11	30.59	52.75	48.73	38.65	14.31	52.60	6.99	48.40
2020/5/8	90.46	6.29	28.62	54.57	47.08	37.55	14.77	53.57	7.13	48.08
2020/5/11	90.93	6.19	27.62	55.96	46.65	37.72	14.71	53.53	6.93	48.20
2020/5/12	88.26	6.00	28.00	55.35	50.25	38.22	14.79	52.27	6.91	48.23
2020/5/13	86.02	5.79	31.18	57.83	50.05	38.46	14.56	51.65	6.60	48.31
2020/5/14	86.55	5.70	31.00	56.00	50.85	38.84	14.84	52.91	6.66	47.67
2020/5/15	86.99	5.49	32.01	54.01	50.07	38.81	14.82	52.92	6.44	47.26
2020/5/18	91.04	6.27	31.45	55.70	50.08	39.60	15.25	53.15	7.13	47.64
2020/5/19	91.51	6.21	31.34	55.40	50.29	40.23	14.80	52.34	7.06	47.20
2020/5/20	92.95	6.42	31.88	56.62	51.87	40.16	15.03	52.90	7.51	47.74
2020/5/21	94.26	6.48	32.66	55.15	54.39	39.55	14.87	52.22	7.36	47.44
2020/5/22	93.75	6.41	35.55	52.68	54.00	40.40	14.89	52.62	7.32	47.30
2020/5/26	96.62	6.80	35.05	53.91	52.60	40.22	15.10	52.78	8.21	47.27
2020/5/27	99.87	7.29	33.38	53.58	55.35	41.19	15.60	53.20	8.68	47.49
2020/5/28	98.46	6.78	35.96	52.25	57.98	41.30	15.77	53.62	8.51	48.68

2020/5/29	98.58	6.57	37.94	54.32	58.07	42.44	15.82	53.77	8.40	49.11
2020/6/1	99.54	6.76	37.00	55.18	59.50	41.67	16.12	53.06	8.69	49.49
2020/6/2	100.74	7.05	39.83	56.36	60.68	40.20	16.33	53.28	8.90	49.89
2020/6/3	104.11	7.36	40.11	56.29	59.41	39.86	16.89	53.49	9.22	49.58
2020/6/4	101.28	7.74	38.97	55.52	58.89	39.81	16.99	52.85	9.49	49.95
2020/6/5	102.71	7.88	38.80	56.00	55.62	39.64	17.01	53.98	9.69	50.10
2020/6/8	104.29	8.46	35.31	55.78	56.15	39.65	17.27	55.10	10.20	50.81
2020/6/9	102.63	8.02	36.02	55.98	55.95	39.82	17.17	54.18	9.82	50.85
2020/6/10	102.12	7.61	35.67	57.99	57.07	40.52	17.23	54.11	9.78	51.54
2020/6/11	95.17	6.95	37.01	55.88	57.26	40.27	16.38	51.31	9.00	49.49
2020/6/12	96.43	7.25	37.01	56.75	57.11	41.16	16.46	51.86	9.39	49.95
2020/6/15	97.84	7.24	36.73	56.83	56.93	39.62	16.80	53.25	9.47	50.59
2020/6/16	99.04	7.47	36.76	58.08	57.36	40.13	16.97	54.59	9.55	51.08
2020/6/17	99.21	7.24	36.71	58.41	58.41	40.40	17.08	51.52	9.34	52.49
2020/6/18	98.45	7.28	37.08	59.21	56.18	39.23	17.00	53.69	9.24	51.43
2020/6/19	95.78	7.15	34.85	58.95	57.08	39.30	17.20	54.40	9.22	52.32
2020/6/22	99.51	7.04	35.83	62.15	55.77	39.57	16.51	55.12	9.35	52.50
2020/6/23	101.92	7.00	35.01	64.00	56.71	39.12	16.86	55.19	9.55	52.47
2020/6/24	100.08	6.53	35.91	62.97	56.82	39.95	16.55	54.44	9.12	51.06
2020/6/25	101.40	6.68	36.15	62.72	56.20	40.15	16.63	54.53	9.57	51.86
2020/6/26	93.67	6.48	35.66	62.20	57.95	40.56	16.25	54.18	9.00	50.91
2020/6/29	95.87	6.80	37.17	62.87	57.26	40.82	16.59	54.76	9.46	51.08
2020/6/30	98.05	6.83	36.67	64.00	58.46	41.07	16.77	55.27	9.52	51.05
2020/7/1	97.40	6.74	37.81	65.02	58.65	40.29	16.73	55.49	9.32	51.27
2020/7/2	98.43	6.82	37.63	66.69	58.02	40.54	16.93	55.94	9.53	51.62
2020/7/6	99.95	7.00	37.19	67.99	57.44	40.14	17.00	56.60	9.95	52.20
2020/7/7	97.07	6.76	36.15	66.50	58.69	40.36	16.77	56.31	9.82	51.43
2020/7/8	98.84	6.86	36.67	70.89	58.80	40.20	16.89	56.66	10.00	51.52
2020/7/9	96.99	6.58	37.29	71.28	57.93	40.23	16.68	57.53	9.72	50.55
2020/7/10	97.99	6.69	36.99	70.40	58.61	40.34	16.94	57.39	10.10	50.28
2020/7/13	96.46	6.70	37.69	68.14	58.77	39.73	16.90	57.01	9.73	50.94
2020/7/14	96.76	6.88	37.67	67.54	59.73	39.79	17.35	57.20	10.02	52.11
2020/5/29	98.58	6.57	37.94	54.32	58.07	42.44	15.82	53.77	8.40	49.11
2020/6/1	99.54	6.76	37.00	55.18	59.50	41.67	16.12	53.06	8.69	49.49
2020/6/2	100.74	7.05	39.83	56.36	60.68	40.20	16.33	53.28	8.90	49.89
2020/6/3	104.11	7.36	40.11	56.29	59.41	39.86	16.89	53.49	9.22	49.58
2020/6/4	101.28	7.74	38.97	55.52	58.89	39.81	16.99	52.85	9.49	49.95
2020/6/5	102.71	7.88	38.80	56.00	55.62	39.64	17.01	53.98	9.69	50.10

2020/6/8	104.29	8.46	35.31	55.78	56.15	39.65	17.27	55.10	10.20	50.81
2020/6/9	102.63	8.02	36.02	55.98	55.95	39.82	17.17	54.18	9.82	50.85
2020/6/10	102.12	7.61	35.67	57.99	57.07	40.52	17.23	54.11	9.78	51.54
2020/6/11	95.17	6.95	37.01	55.88	57.26	40.27	16.38	51.31	9.00	49.49
2020/6/12	96.43	7.25	37.01	56.75	57.11	41.16	16.46	51.86	9.39	49.95
2020/6/15	97.84	7.24	36.73	56.83	56.93	39.62	16.80	53.25	9.47	50.59
2020/6/16	99.04	7.47	36.76	58.08	57.36	40.13	16.97	54.59	9.55	51.08
2020/6/17	99.21	7.24	36.71	58.41	58.41	40.40	17.08	51.52	9.34	52.49
2020/6/18	98.45	7.28	37.08	59.21	56.18	39.23	17.00	53.69	9.24	51.43
2020/6/19	95.78	7.15	34.85	58.95	57.08	39.30	17.20	54.40	9.22	52.32
2020/6/22	99.51	7.04	35.83	62.15	55.77	39.57	16.51	55.12	9.35	52.50
2020/6/23	101.92	7.00	35.01	64.00	56.71	39.12	16.86	55.19	9.55	52.47
2020/6/24	100.08	6.53	35.91	62.97	56.82	39.95	16.55	54.44	9.12	51.06
2020/6/25	101.40	6.68	36.15	62.72	56.20	40.15	16.63	54.53	9.57	51.86
2020/6/26	93.67	6.48	35.66	62.20	57.95	40.56	16.25	54.18	9.00	50.91
2020/6/29	95.87	6.80	37.17	62.87	57.26	40.82	16.59	54.76	9.46	51.08
2020/6/30	98.05	6.83	36.67	64.00	58.46	41.07	16.77	55.27	9.52	51.05
2020/7/1	97.40	6.74	37.81	65.02	58.65	40.29	16.73	55.49	9.32	51.27
2020/7/2	98.43	6.82	37.63	66.69	58.02	40.54	16.93	55.94	9.53	51.62
2020/7/6	99.95	7.00	37.19	67.99	57.44	40.14	17.00	56.60	9.95	52.20
2020/7/7	97.07	6.76	36.15	66.50	58.69	40.36	16.77	56.31	9.82	51.43
2020/7/8	98.84	6.86	36.67	70.89	58.80	40.20	16.89	56.66	10.00	51.52
2020/7/9	96.99	6.58	37.29	71.28	57.93	40.23	16.68	57.53	9.72	50.55
2020/7/10	97.99	6.69	36.99	70.40	58.61	40.34	16.94	57.39	10.10	50.28
2020/7/13	96.46	6.70	37.69	68.14	58.77	39.73	16.90	57.01	9.73	50.94
2020/7/14	96.76	6.88	37.67	67.54	59.73	39.79	17.35	57.20	10.02	52.11
2020/7/15	98.54	7.14	39.33	69.81	59.10	40.38	17.35	56.62	10.19	53.27
2020/7/16	97.26	7.05	38.89	67.08	60.82	41.48	17.47	55.82	10.04	52.96
2020/7/17	96.28	7.07	39.47	67.56	59.94	41.41	17.57	54.90	9.97	53.26
2020/7/20	95.65	6.87	39.16	69.00	61.15	41.03	17.68	55.40	10.18	53.77
2020/7/21	98.36	7.04	40.83	71.49	60.22	40.76	17.78	55.91	9.74	53.22
2020/7/22	98.91	7.06	39.95	69.84	59.75	40.30	17.67	56.01	9.83	53.33
2020/7/23	98.30	7.04	40.07	70.44	59.80	40.92	17.55	55.76	9.62	52.13
2020/7/24	98.43	6.86	39.83	68.82	58.29	42.01	17.36	55.65	9.61	51.15
2020/7/27	97.21	6.71	39.90	68.33	56.16	41.10	17.38	55.34	9.55	52.19
2020/7/28	96.27	6.89	38.60	69.12	54.70	41.20	17.25	55.35	9.45	51.83
2020/7/29	96.97	6.59	37.40	70.42	56.21	41.89	17.35	55.70	9.22	52.84
2020/7/30	96.82	6.26	39.06	69.06	58.14	42.31	17.10	55.25	9.00	52.50

2020/7/31	97.61	6.07	40.15	68.49	56.13	43.77	16.66	55.45	8.92	52.45
2020/8/3	98.33	6.11	40.81	69.60	55.23	43.55	17.00	55.98	9.22	53.21
2020/8/4	97.33	6.14	40.61	71.19	54.90	44.10	17.32	56.00	9.25	51.79
2020/8/5	100.94	6.40	40.60	72.45	55.35	43.95	17.24	55.50	9.34	51.61
2020/8/6	100.45	6.33	40.88	72.57	58.54	44.06	17.26	55.28	9.22	51.50
2020/8/7	101.86	6.40	42.29	67.22	58.87	44.53	17.54	55.23	9.22	51.51
2020/8/10	105.41	6.67	42.62	64.89	58.28	43.67	17.54	54.94	9.42	50.91
2020/8/11	105.12	6.73	42.31	65.95	58.22	43.40	17.49	54.27	9.56	50.82
2020/8/12	105.22	6.72	42.26	68.00	57.88	43.40	17.90	54.17	9.71	51.79
2020/8/13	106.52	6.60	42.33	65.32	57.56	43.26	18.05	54.02	9.55	51.37
2020/8/14	106.43	6.66	42.22	64.87	58.25	43.70	18.15	54.20	9.52	50.33
2020/8/17	105.66	6.47	42.92	66.09	57.39	44.43	18.02	53.99	9.46	51.35
2020/8/18	106.97	6.44	41.97	66.07	56.81	44.25	17.94	55.18	9.40	52.02
2020/8/19	108.39	6.38	41.13	64.90	58.25	44.75	17.95	56.20	9.54	51.72
2020/8/20	108.01	6.27	42.79	66.26	57.95	44.41	17.83	55.26	9.34	51.40
2020/8/21	109.75	6.31	42.33	69.55	59.42	44.91	17.54	55.19	9.18	50.86
2020/8/24	111.83	6.63	43.03	69.96	59.60	44.61	17.84	56.01	9.59	51.52
2020/8/25	111.51	6.59	43.00	71.17	59.61	44.56	18.02	56.09	9.64	51.73
2020/8/26	111.53	6.48	42.88	71.21	60.15	44.64	17.95	57.49	9.81	51.65
2020/8/27	110.84	6.48	42.65	71.11	60.13	45.00	17.85	57.18	9.73	50.76
2020/8/28	112.29	6.61	42.67	70.32	60.39	45.89	17.79	57.88	9.89	50.20
2020/8/31	111.89	6.34	43.08	68.34	60.80	46.20	17.62	57.22	9.53	50.58
2020/9/1	114.84	6.19	43.34	70.51	61.38	43.49	17.40	57.66	9.52	49.94
2020/9/2	116.80	6.44	43.48	70.13	62.58	44.43	18.29	59.03	9.45	50.47
2020/9/3	112.85	6.32	45.10	67.22	63.17	44.87	18.02	57.10	9.29	49.78
2020/9/4	112.40	6.42	45.58	67.05	63.74	45.50	17.92	55.73	9.73	49.47
2020/9/8	112.72	6.14	46.39	64.74	63.74	45.85	17.60	55.32	9.41	50.38
2020/9/9	114.90	6.16	46.51	66.33	64.31	45.55	18.18	56.95	9.42	51.63
2020/9/10	114.79	6.00	46.54	64.98	64.12	43.92	18.00	57.33	9.35	50.70
2020/9/11	118.00	5.95	46.17	66.19	64.32	44.38	18.06	57.00	9.26	51.88
2020/9/14	119.28	6.15	46.00	68.46	64.71	44.87	18.06	59.46	9.34	51.68
2020/9/15	119.27	6.10	46.29	68.98	64.81	44.50	18.03	60.94	9.10	52.54
2020/9/16	118.59	6.75	46.40	68.32	63.74	44.45	17.88	60.43	9.29	51.81
2020/7/31	97.61	6.07	40.15	68.49	56.13	43.77	16.66	55.45	8.92	52.45
2020/8/3	98.33	6.11	40.81	69.60	55.23	43.55	17.00	55.98	9.22	53.21
2020/8/4	97.33	6.14	40.61	71.19	54.90	44.10	17.32	56.00	9.25	51.79
2020/8/5	100.94	6.40	40.60	72.45	55.35	43.95	17.24	55.50	9.34	51.61
2020/8/6	100.45	6.33	40.88	72.57	58.54	44.06	17.26	55.28	9.22	51.50

2020/8/7	101.86	6.40	42.29	67.22	58.87	44.53	17.54	55.23	9.22	51.51
2020/8/10	105.41	6.67	42.62	64.89	58.28	43.67	17.54	54.94	9.42	50.91
2020/8/11	105.12	6.73	42.31	65.95	58.22	43.40	17.49	54.27	9.56	50.82
2020/8/12	105.22	6.72	42.26	68.00	57.88	43.40	17.90	54.17	9.71	51.79
2020/8/13	106.52	6.60	42.33	65.32	57.56	43.26	18.05	54.02	9.55	51.37
2020/8/14	106.43	6.66	42.22	64.87	58.25	43.70	18.15	54.20	9.52	50.33
2020/8/17	105.66	6.47	42.92	66.09	57.39	44.43	18.02	53.99	9.46	51.35
2020/8/18	106.97	6.44	41.97	66.07	56.81	44.25	17.94	55.18	9.40	52.02
2020/8/19	108.39	6.38	41.13	64.90	58.25	44.75	17.95	56.20	9.54	51.72
2020/8/20	108.01	6.27	42.79	66.26	57.95	44.41	17.83	55.26	9.34	51.40
2020/8/21	109.75	6.31	42.33	69.55	59.42	44.91	17.54	55.19	9.18	50.86
2020/8/24	111.83	6.63	43.03	69.96	59.60	44.61	17.84	56.01	9.59	51.52
2020/8/25	111.51	6.59	43.00	71.17	59.61	44.56	18.02	56.09	9.64	51.73
2020/8/26	111.53	6.48	42.88	71.21	60.15	44.64	17.95	57.49	9.81	51.65
2020/8/27	110.84	6.48	42.65	71.11	60.13	45.00	17.85	57.18	9.73	50.76
2020/8/28	112.29	6.61	42.67	70.32	60.39	45.89	17.79	57.88	9.89	50.20
2020/8/31	111.89	6.34	43.08	68.34	60.80	46.20	17.62	57.22	9.53	50.58
2020/9/1	114.84	6.19	43.34	70.51	61.38	43.49	17.40	57.66	9.52	49.94
2020/9/2	116.80	6.44	43.48	70.13	62.58	44.43	18.29	59.03	9.45	50.47
2020/9/3	112.85	6.32	45.10	67.22	63.17	44.87	18.02	57.10	9.29	49.78
2020/9/4	112.40	6.42	45.58	67.05	63.74	45.50	17.92	55.73	9.73	49.47
2020/9/8	112.72	6.14	46.39	64.74	63.74	45.85	17.60	55.32	9.41	50.38
2020/9/9	114.90	6.16	46.51	66.33	64.31	45.55	18.18	56.95	9.42	51.63
2020/9/10	114.79	6.00	46.54	64.98	64.12	43.92	18.00	57.33	9.35	50.70
2020/9/11	118.00	5.95	46.17	66.19	64.32	44.38	18.06	57.00	9.26	51.88
2020/9/14	119.28	6.15	46.00	68.46	64.71	44.87	18.06	59.46	9.34	51.68
2020/9/15	119.27	6.10	46.29	68.98	64.81	44.50	18.03	60.94	9.10	52.54
2020/9/16	118.59	6.75	46.40	68.32	63.74	44.45	17.88	60.43	9.29	51.81
2020/9/17	116.36	7.05	45.48	66.66	60.49	42.65	17.94	60.18	9.24	52.07
2020/9/18	114.66	6.88	43.49	67.02	60.58	43.01	17.77	59.75	9.09	52.44
2020/9/21	113.37	6.35	43.73	66.57	60.96	42.50	17.17	60.82	8.34	50.85
2020/9/22	116.87	6.25	44.29	66.38	60.64	42.90	17.05	60.62	8.14	49.86
2020/9/23	127.11	6.11	44.49	65.50	59.06	42.39	16.67	58.96	8.05	50.61
2020/9/24	124.75	6.06	44.19	65.62	61.73	42.41	16.74	59.30	8.11	50.79
2020/9/25	124.23	6.11	45.88	65.31	62.00	42.41	16.64	59.80	8.00	50.78
2020/9/28	124.32	6.20	45.69	65.64	61.99	42.69	16.75	59.58	8.43	51.00
2020/9/29	126.35	6.12	46.04	65.55	62.66	43.23	16.79	59.47	8.27	50.50
2020/9/30	125.54	6.23	46.74	67.65	62.36	43.68	16.85	59.70	8.40	50.17

2020/10/1	126.64	6.24	46.75	68.52	64.03	44.06	17.03	59.68	8.36	49.96
2020/10/2	126.64	6.39	47.83	67.23	64.85	44.05	17.10	58.83	8.50	50.48
2020/10/5	127.91	6.41	48.13	68.39	65.74	44.00	17.39	59.56	8.70	50.98
2020/10/6	127.65	6.17	49.09	68.81	65.72	44.33	17.18	59.51	9.01	49.73
2020/10/7	130.06	6.31	48.82	69.32	64.70	44.61	17.12	60.59	9.23	49.50
2020/10/8	129.71	6.65	48.18	69.56	65.09	45.28	17.05	60.89	9.36	50.36
2020/10/9	130.98	6.84	49.01	70.94	64.25	44.92	17.09	61.15	9.28	50.81
2020/10/12	129.46	6.83	48.88	73.08	64.08	45.25	17.15	61.46	9.34	51.08
2020/10/13	129.20	6.72	48.28	74.04	62.17	44.69	17.10	60.97	9.11	51.47
2020/10/14	127.66	6.82	46.83	73.00	63.12	44.53	16.97	60.96	9.06	51.14
2020/10/15	129.00	6.87	49.40	71.95	63.62	44.84	16.49	60.52	9.02	49.96
2020/10/16	128.00	7.29	48.81	72.72	64.07	44.53	16.43	60.29	9.25	50.27
2020/10/19	127.43	7.29	48.68	72.13	63.81	43.54	16.29	59.62	9.28	50.14
2020/10/20	128.49	7.34	47.97	72.75	64.01	43.70	16.16	59.75	9.60	49.88
2020/10/21	129.43	7.32	47.90	72.89	63.93	43.58	16.00	59.67	9.41	49.17
2020/10/22	130.02	7.72	48.40	72.20	63.21	43.16	15.86	59.69	9.45	48.93
2020/10/23	129.99	7.63	47.97	73.03	61.47	43.49	15.96	59.90	9.65	49.33
2020/10/26	128.37	7.38	47.06	72.59	58.06	41.85	15.68	57.49	9.54	49.13
2020/10/27	127.99	7.10	44.24	76.75	58.33	43.35	15.40	57.08	9.25	47.40
2020/10/28	122.08	7.42	44.22	75.95	58.68	43.33	15.02	55.59	9.25	46.14
2020/10/29	122.86	7.37	44.40	78.53	59.68	43.79	15.43	56.02	9.24	45.51
2020/10/30	120.08	7.42	45.82	76.34	62.12	44.20	15.30	56.11	9.25	45.30
2020/11/2	122.39	7.52	47.20	77.48	62.52	46.29	15.54	56.45	9.64	46.41
2020/11/3	124.59	7.85	48.02	74.97	64.79	46.31	15.89	56.80	9.96	47.55
2020/11/4	127.34	7.85	49.42	78.71	63.58	46.24	16.03	56.49	9.92	50.59
2020/11/5	129.70	7.99	48.17	80.83	67.63	43.12	16.43	56.66	10.05	50.33
2020/11/6	128.90	8.09	50.70	79.76	69.50	41.36	16.85	56.80	10.15	49.25
2020/11/9	128.95	8.72	53.00	78.56	70.34	43.50	17.28	56.84	10.62	49.63
2020/11/10	127.71	8.98	52.99	73.80	70.70	42.89	17.50	56.67	10.72	50.17
2020/11/11	127.66	8.89	52.20	73.44	70.74	42.49	17.64	57.20	10.48	51.62
2020/11/12	126.64	8.76	52.50	73.30	72.79	40.79	17.64	56.45	10.41	51.04
2020/11/13	128.28	9.25	53.78	76.46	72.85	40.69	17.71	56.91	10.73	51.01
2020/11/16	130.11	9.57	54.54	75.83	73.87	42.35	17.55	57.15	10.79	50.67
2020/11/17	132.21	9.68	55.70	75.02	74.00	42.48	17.76	57.12	10.82	50.27
2020/11/18	131.63	9.73	55.07	75.47	74.15	42.62	17.63	56.25	10.72	50.50
2020/11/19	131.91	9.66	55.52	75.18	73.89	41.08	17.70	56.45	10.75	50.88
2020/11/20	132.98	9.76	56.00	76.40	76.68	40.17	17.61	55.70	10.69	50.52
2020/11/23	134.13	10.07	57.95	74.67	75.40	40.72	17.52	56.08	11.04	49.85

2020/11/24	134.70	10.45	57.41	75.79	74.13	41.00	17.69	57.57	11.46	49.92
2020/11/25	135.54	10.50	56.09	74.75	73.09	41.00	17.97	57.41	11.37	50.20
2020/11/27	134.25	10.40	56.59	75.95	73.04	42.04	18.11	57.76	11.36	51.13
2020/11/30	134.70	10.18	56.45	73.00	74.78	41.07	18.06	57.72	11.12	50.20
2020/12/1	135.44	10.15	57.54	74.60	74.33	41.48	18.27	58.74	11.45	50.93
2020/12/2	135.58	10.43	57.49	74.50	74.29	42.00	18.32	59.08	11.58	50.62
2020/12/3	136.96	10.60	56.77	76.45	74.95	41.82	18.22	59.27	11.77	50.11
2020/12/4	137.19	10.88	58.21	75.73	73.70	42.14	18.46	59.96	11.77	51.03
2020/12/7	138.75	10.86	57.70	75.83	73.01	42.61	18.38	59.80	11.58	49.90
2020/12/8	139.12	10.96	57.50	75.83	73.13	42.11	18.33	59.03	11.44	49.63
2020/12/9	138.79	11.39	57.52	74.59	71.36	42.51	18.18	59.73	11.23	49.61
2020/12/10	137.58	11.32	56.32	75.84	70.51	42.71	18.23	59.48	11.00	49.74
2020/12/11	137.41	11.16	55.51	75.14	71.91	42.72	17.84	60.61	10.62	47.83
2020/12/14	136.28	10.83	56.37	73.16	73.86	42.59	17.96	60.76	10.61	46.69
2020/12/15	139.39	11.11	57.98	73.12	74.43	43.11	18.14	61.86	10.85	46.29
2020/12/16	138.34	10.93	58.77	74.06	73.78	43.58	18.30	62.78	10.95	47.11
2020/12/17	140.50	10.88	58.54	75.28	74.19	42.90	18.44	63.61	11.13	47.48
2020/12/18	137.28	10.81	58.67	75.31	71.97	42.12	18.53	65.06	11.07	48.12
2020/12/21	144.02	10.77	56.39	73.89	72.10	42.38	18.01	64.48	10.65	47.02
2020/12/22	142.45	10.61	56.64	73.29	73.38	42.58	17.80	65.15	10.62	47.81
2020/12/23	141.76	10.86	58.52	73.65	73.49	43.25	18.06	65.30	10.93	47.58
2020/12/24	141.60	10.65	58.65	69.75	73.16	43.57	18.07	64.96	10.85	47.45
2020/12/28	142.43	10.64	58.19	67.28	72.23	43.69	18.41	64.87	11.19	47.93
2020/12/29	141.57	10.56	57.79	69.86	71.86	43.50	18.50	64.46	10.94	48.26
2020/12/30	141.58	10.71	56.90	71.72	70.86	43.25	18.44	64.40	10.89	48.36
2020/12/31	141.47	10.80	56.89	71.89	70.99	41.60	18.27	64.69	10.90	48.59
2021/1/4	140.10	10.47	56.43	72.85	71.02	41.61	18.53	63.75	10.74	48.75
2021/1/5	141.23	10.77	57.79	76.66	70.49	42.07	18.49	62.96	10.94	48.74
2021/1/6	142.35	11.36	57.69	73.62	69.30	41.88	18.64	62.57	11.53	48.01
2021/1/7	144.95	11.27	57.15	72.85	69.84	40.89	18.85	63.07	11.68	48.09
2021/1/8	146.35	11.34	58.13	76.94	69.12	41.53	18.69	63.38	11.66	48.45
2021/1/11	147.05	11.45	57.23	75.75	69.78	41.90	18.44	63.03	11.65	48.05
2021/1/12	145.05	11.78	57.81	76.22	69.41	41.30	18.43	62.42	11.81	48.35
2021/1/13	143.04	11.57	56.26	78.43	69.49	41.79	18.46	62.06	11.72	48.04
2021/1/14	141.30	11.66	56.67	80.80	68.34	42.04	18.45	61.60	12.13	49.03
2021/1/15	140.72	11.33	55.60	82.25	70.79	42.29	18.19	61.78	11.62	49.39
2021/1/19	139.27	11.43	57.91	85.90	71.28	41.70	18.32	61.29	11.25	50.51
2021/1/20	142.80	11.39	59.04	88.07	71.25	41.72	18.47	61.56	11.11	49.91

2021/1/21	141.61	11.07	59.07	88.44	70.21	41.95	18.48	61.21	11.18	49.64
2021/1/22	139.35	11.11	57.44	90.35	72.08	42.18	18.41	60.36	10.89	49.69
2021/1/25	137.55	10.99	58.89	96.00	71.31	41.44	18.22	60.90	10.50	49.63
2021/1/26	135.10	11.29	57.25	92.36	70.91	40.95	18.29	61.80	10.67	49.15
2021/1/27	131.02	11.38	57.59	88.21	70.01	40.88	18.24	62.55	10.29	47.33
2021/1/28	134.72	11.09	58.12	89.81	69.88	42.30	18.23	61.22	10.49	47.57
2021/1/29	133.59	10.68	58.39	89.31	71.41	42.54	17.88	60.43	10.12	47.21
2021/2/1	135.71	10.74	59.28	93.91	71.73	42.02	17.95	61.51	10.37	47.60
2021/2/2	139.59	11.24	64.56	94.60	70.77	41.95	18.10	62.37	10.45	47.27
2021/2/3	138.63	11.20	65.90	94.00	70.05	41.43	18.42	62.17	10.54	46.87
2021/2/4	140.63	11.45	66.99	95.39	69.81	41.07	18.40	63.35	10.41	47.12
2021/2/5	145.11	11.40	66.40	95.40	70.09	41.42	18.20	63.60	10.32	48.21
2021/2/8	143.41	11.61	65.80	95.10	70.00	41.13	18.17	63.11	10.56	48.63
2021/2/9	141.79	11.54	65.09	97.79	70.58	41.40	18.14	63.67	10.47	48.86
2021/2/10	142.46	11.40	65.05	97.75	70.25	41.27	18.03	63.27	10.59	48.07
2021/2/11	143.54	11.46	64.66	98.69	70.76	41.36	18.00	62.70	10.68	47.70
2021/2/12	142.12	11.73	64.84	99.10	70.92	40.61	18.03	63.08	10.89	47.57
2021/2/16	141.71	11.97	65.01	96.10	70.86	40.32	17.94	62.14	11.35	47.45
2021/2/17	143.99	11.86	65.44	97.31	71.03	40.17	17.91	62.09	11.27	47.61
2021/2/18	145.09	11.63	66.89	95.74	71.58	39.86	17.83	62.07	11.17	47.31
2021/2/19	142.02	12.02	67.22	95.50	71.27	39.75	17.93	61.13	11.63	46.64
2021/2/22	136.67	12.50	66.80	90.29	69.32	39.79	17.94	64.45	11.99	46.36
2021/2/23	136.13	12.59	65.33	90.73	70.39	39.29	17.89	64.50	12.03	46.41
2021/2/24	135.65	13.12	65.84	89.20	71.50	39.07	17.97	64.70	12.44	46.61
2021/2/25	135.54	12.76	65.93	86.77	71.50	38.95	18.09	65.30	12.75	45.80
2021/2/26	134.78	12.54	66.25	87.20	72.10	39.30	18.15	64.51	12.27	45.89
2021/3/1	137.65	13.11	66.61	91.30	72.56	39.37	18.05	66.17	12.63	45.91
2021/3/2	137.02	12.98	68.27	89.91	76.10	38.66	18.14	66.66	12.63	45.94
2021/3/3	134.26	13.44	69.38	90.34	76.29	38.93	17.98	66.91	12.83	45.46
2021/3/4	132.04	13.57	70.58	86.90	75.67	38.21	17.86	65.61	12.34	45.90
2021/3/5	133.35	13.60	70.22	87.25	79.64	38.77	17.99	69.97	12.71	46.59
2021/3/8	134.56	14.17	72.49	82.20	79.59	38.53	18.14	72.16	13.15	46.59
2021/3/9	135.95	14.00	71.91	85.87	81.34	38.83	18.32	72.64	12.69	47.17
2021/3/10	137.59	13.25	72.64	84.59	78.52	38.99	19.27	72.12	12.82	47.95
2021/3/11	141.19	12.27	72.09	89.28	77.48	38.76	19.42	67.41	12.54	47.84
2021/3/12	140.45	12.58	70.72	82.57	77.80	38.95	19.80	67.16	12.72	48.01
2021/3/15	144.94	13.35	70.08	82.62	80.50	39.75	19.85	67.73	12.50	48.71
2021/3/16	144.65	13.15	71.26	81.65	85.46	39.30	19.65	66.85	12.38	49.40

2021/3/22	138.27	13.13	74.16	82.77	83.43	41.36	19.65	66.32	12.61	49.29
2021/3/23	137.12	12.66	72.61	80.93	82.59	40.41	19.85	67.27	12.29	48.54
2021/3/24	133.16	12.50	71.65	76.81	83.50	38.94	19.74	66.83	12.40	48.55
2021/3/25	128.64	12.85	72.50	77.42	83.79	40.45	19.85	68.63	12.34	49.18
2021/3/26	132.99	12.99	73.27	80.98	85.60	39.46	19.95	70.25	12.35	49.63
2021/3/29	133.49	12.95	73.71	78.69	87.47	39.85	20.29	71.13	11.95	49.63

Annex 4: Covariance matrix

	NIKE	GE	DAI.DE	TCEHY	BMW	DWNI.DE	DTEGY	ORCL	DB	SNY
NIKE	0.00037	0.00021	-0.00001	0.00015	-0.00001	0.00000	0.00011	0.00009	0.00022	0.00008
GE	0.00021	0.00108	-0.00005	0.00004	-0.00008	-0.00002	0.00018	0.00014	0.00061	0.00006
DAI.DE	-0.00001	-0.00005	0.00076	-0.00003	-0.00002	0.00002	-0.00003	-0.00001	-0.00008	0.00004
TCEHY	0.00015	0.00004	-0.00003	0.00064	0.00000	0.00001	0.00004	0.00006	0.00009	0.00009
BMW	-0.00001	-0.00008	-0.00002	0.00000	0.00052	0.00002	0.00003	0.00001	-0.00003	0.00003
DWNI.DE	0.00000	-0.00002	0.00002	0.00001	0.00002	0.00027	0.00000	0.00001	0.00003	0.00001
DTEGY	0.00011	0.00018	-0.00003	0.00004	0.00003	0.00000	0.00023	0.00009	0.00026	0.00008
ORCL	0.00009	0.00014	-0.00001	0.00006	0.00001	0.00001	0.00009	0.00025	0.00014	0.00004
DB	0.00022	0.00061	-0.00008	0.00009	-0.00003	0.00003	0.00026	0.00014	0.00092	0.00009
SNY	0.00008	0.00006	0.00004	0.00009	0.00003	0.00001	0.00008	0.00004	0.00009	0.00023

Annex 5: Yield curves derived from the annual transition

matrix 1st year: 2021

	AAA	AA+	AA	AA-	A+	A	A-	BBB+	BBB	BBB-	BB+	BB	BB-	B+	B	B-	CCC	D
AAA	72.38%	10.76%	3.54%	1.72%	0.60%	0.81%	0.11%	0.07%	0.35%	0.04%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
AA+	1.78%	56.30%	23.27%	5.43%	2.23%	1.63%	1.10%	0.92%	0.10%	0.42%	0.02%	0.01%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
AA	0.38%	1.87%	62.98%	13.36%	7.45%	2.73%	1.22%	0.45%	0.07%	0.19%	0.01%	0.01%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
AA-	0.14%	0.19%	7.12%	57.31%	18.59%	5.54%	2.54%	0.49%	0.24%	0.28%	0.02%	0.01%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
A+	0.01%	0.14%	1.25%	8.35%	55.96%	16.41%	5.20%	1.22%	0.72%	0.18%	0.02%	0.02%	0.01%	0.01%	0.00%	0.00%	0.00%	0.01%
A	0.01%	0.35%	0.38%	1.40%	7.13%	55.34%	17.08%	4.37%	2.03%	0.46%	0.14%	0.13%	0.11%	0.09%	0.01%	0.00%	0.01%	0.20%
A-	0.08%	0.02%	0.28%	0.37%	1.86%	10.99%	59.37%	12.16%	3.01%	1.42%	0.33%	0.18%	0.18%	0.04%	0.02%	0.00%	0.02%	0.11%
BBB+	0.00%	0.00%	0.03%	0.24%	0.58%	1.89%	11.31%	55.34%	12.73%	2.51%	0.78%	0.93%	0.37%	0.34%	0.16%	0.04%	0.16%	0.20%
BBB	0.00%	0.00%	0.17%	0.04%	0.35%	1.04%	1.99%	11.53%	50.40%	11.15%	2.80%	1.76%	0.33%	0.29%	0.52%	0.17%	0.18%	0.27%
BBB-	0.00%	0.00%	0.25%	0.03%	0.29%	1.02%	0.98%	2.82%	12.41%	46.76%	8.68%	4.06%	1.37%	0.74%	0.51%	0.08%	0.37%	0.71%
BB+	0.00%	0.00%	0.02%	0.00%	0.03%	0.11%	0.53%	1.10%	2.26%	14.90%	36.28%	9.91%	3.58%	2.64%	0.70%	0.13%	0.40%	0.27%
BB	0.00%	0.00%	0.00%	0.00%	0.01%	0.04%	0.41%	0.77%	0.32%	3.51%	13.14%	33.80%	7.78%	4.20%	1.58%	0.29%	0.75%	1.26%
BB-	0.00%	0.00%	0.00%	0.00%	0.00%	0.03%	0.03%	0.10%	0.35%	0.54%	1.36%	10.71%	36.58%	15.36%	5.60%	1.40%	0.72%	2.95%
B+	0.00%	0.00%	0.00%	0.00%	0.01%	0.30%	0.05%	0.32%	0.07%	0.13%	0.65%	4.10%	10.32%	32.13%	9.06%	4.85%	2.11%	4.19%
B	0.00%	0.00%	0.00%	0.00%	0.00%	0.03%	0.00%	0.04%	0.09%	0.48%	0.50%	0.92%	2.68%	12.48%	22.61%	8.78%	4.70%	8.85%
B-	0.00%	0.00%	0.00%	0.00%	0.00%	0.01%	0.01%	0.05%	0.75%	0.07%	0.04%	0.07%	0.21%	2.27%	6.67%	26.40%	12.12%	21.42%
CCC	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.06%	0.01%	0.02%	0.05%	0.15%	1.45%	3.13%	7.20%	8.02%	48.62%
D	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	100.00%

10th year: 2030

From/To	AAA	AA+	AA	AA-	A+	A	A-	BBB+	BBB	BBB-	BB+	BB	BB-	B+	B	B-	CCC	D
AAA	17.63	9.04	11.12	6.44	5.11	3.78	2.54	1.30	0.81	0.44	0.12	0.08	0.04	0.03	0.02	0.01	0.01	0.07
AA+	1.75	5.76	15.60	10.80	9.89	7.13	5.31	2.64	1.36	0.77	0.23	0.17	0.09	0.07	0.04	0.01	0.02	0.15
AA	0.57	1.43	11.94	11.17	11.66	8.85	6.52	2.94	1.50	0.74	0.23	0.16	0.09	0.07	0.03	0.01	0.02	0.16
AA-	0.26	0.61	5.80	10.61	13.12	11.34	8.91	4.11	2.16	1.00	0.33	0.24	0.13	0.10	0.05	0.02	0.02	0.25
A+	0.11	0.35	2.61	5.90	10.61	12.15	10.96	5.57	2.99	1.34	0.46	0.34	0.19	0.15	0.08	0.03	0.04	0.40
A	0.09	0.28	1.25	2.63	5.76	11.18	13.30	7.99	4.48	2.11	0.78	0.59	0.33	0.26	0.14	0.06	0.06	0.94
A-	0.11	0.16	0.74	1.49	3.61	8.63	14.05	9.99	5.86	2.91	1.12	0.84	0.46	0.37	0.20	0.09	0.09	0.99
BBB+	0.04	0.06	0.37	0.72	1.79	4.54	8.95	10.20	7.42	4.00	1.66	1.25	0.67	0.57	0.32	0.15	0.14	1.70
BBB	0.02	0.04	0.28	0.40	0.98	2.39	4.64	6.73	7.14	4.94	2.22	1.61	0.88	0.75	0.41	0.20	0.17	2.31
BBB-	0.01	0.03	0.26	0.30	0.69	1.58	2.75	4.09	5.23	5.08	2.60	1.94	1.18	1.02	0.52	0.27	0.21	3.54
BB+	0.00	0.01	0.10	0.11	0.28	0.73	1.33	2.07	2.89	3.59	2.33	1.94	1.37	1.25	0.61	0.34	0.23	3.66
BB	0.00	0.01	0.05	0.05	0.14	0.39	0.73	1.10	1.48	2.16	1.76	1.74	1.45	1.39	0.68	0.41	0.25	5.96
BB-	0.00	0.00	0.02	0.02	0.06	0.18	0.30	0.47	0.64	1.05	1.15	1.61	1.86	1.99	1.03	0.71	0.39	12.04
B+	0.00	0.00	0.01	0.02	0.07	0.18	0.26	0.34	0.39	0.59	0.66	1.01	1.26	1.47	0.80	0.62	0.33	15.34
B	0.00	0.00	0.01	0.01	0.02	0.08	0.11	0.18	0.23	0.32	0.34	0.53	0.69	0.89	0.53	0.46	0.25	22.09
B-	0.00	0.00	0.00	0.01	0.02	0.05	0.08	0.15	0.19	0.16	0.13	0.20	0.27	0.41	0.29	0.32	0.17	40.74
CCC	0.00	0.00	0.00	0.00	0.00	0.01	0.02	0.03	0.05	0.05	0.05	0.08	0.12	0.17	0.12	0.12	0.07	56.98
D	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	100.00

Annex 6: Random variables

Scenarios	NIKE	GE	DAI.DE	TCEH)	BMW	DWNI.DE	DTEGY	ORCL	DB	SNY
1	-0.1996	-1.0658	-0.0445	0.6059	-0.3537	-0.3181	-2.4291	-0.4287	-0.1037	1.6237
2	1.1060	0.0867	-1.9184	-0.6807	-0.2745	-0.4315	0.0647	2.6249	0.3864	-0.3379
3	-1.6697	-0.2960	-1.0943	-0.1827	1.2703	2.0312	-0.8347	0.8668	0.3991	-0.9792
4	1.0423	0.0752	0.3127	-0.2541	-1.4047	1.9381	-1.3801	-1.3120	-0.2666	1.4375
5	-0.6514	-0.3702	0.4776	0.2463	-0.3369	-0.2392	-1.3709	0.3761	0.6202	1.6417
6	-2.0616	0.5435	-0.6154	-0.6145	-1.8759	-0.0375	-0.4130	-0.4522	0.2503	1.6102
7	-0.4524	0.3934	0.2159	0.2871	1.0202	-0.4462	-0.1157	0.0460	-1.8963	0.7980
8	1.5133	0.9961	0.6167	0.7950	-0.5677	0.6692	-1.1481	-0.6201	0.8391	-0.0156
9	0.1284	-0.1789	0.6101	-0.5921	-1.7428	0.7492	-0.6203	1.4025	-0.1862	-0.2213
10	0.6860	1.1561	-0.1742	-0.2087	0.6869	0.2884	0.3986	-0.0343	-0.9253	1.2329
11	1.0744	0.5810	-1.4051	1.9426	-0.1209	0.7604	-0.4838	-0.5066	0.2374	-0.8351
12	0.4725	0.4717	0.8819	-0.8577	0.6520	-0.1605	0.0983	0.2887	1.5675	0.5302
13	-0.0146	-0.0551	-0.8386	-0.6956	-0.5797	0.7634	0.3721	1.3825	-1.0633	0.9962
14	0.2669	-0.5886	-0.6266	-1.5353	0.1608	-0.3200	0.0551	-0.6233	-0.8560	-0.6875
15	-1.2895	-0.0454	-0.9882	-0.9435	1.1410	-0.2082	0.8639	-0.8466	1.9238	-0.2117
16	-0.1853	1.7453	-0.2215	-0.9659	-0.6553	-0.3832	-0.7821	1.7499	0.9487	-1.5265
17	1.5489	0.7109	1.1422	0.0526	1.9316	1.2530	-0.2499	-0.6829	0.1908	0.2659
18	-1.0959	-0.8475	2.6988	-0.5602	1.6344	-1.3590	0.3288	0.4385	-0.1363	-0.7253
19	0.2046	0.5602	-0.3107	1.9701	0.2027	0.0768	-2.1348	-1.0041	0.2828	-1.2931
20	-1.0144	0.6798	-0.8464	-1.9282	1.2756	-1.1840	0.6349	-0.8360	1.2193	1.6853
21	0.7658	0.1143	-1.1573	-0.1229	0.4551	0.5399	-1.8083	0.5246	0.0038	1.4911
22	1.8746	1.1229	0.3446	1.5532	0.6216	-0.8785	1.4678	-1.9436	-0.3589	-0.5842
23	1.1137	-0.7358	0.6968	0.9739	0.2812	0.9184	-0.3038	-0.7577	-0.4023	1.1422
24	0.2614	-2.2448	0.9382	-0.6779	1.4453	1.6220	0.1374	0.6051	0.5055	-0.1418
25	-0.1372	0.2331	-0.0840	-1.3623	-0.1612	-0.1445	0.5508	-0.8477	1.4078	0.0417
26	1.6060	2.2622	-0.2024	-0.5122	-1.6710	-0.4585	-0.2653	0.6220	0.8347	0.3856
27	0.2803	0.5451	-0.2447	-1.3018	1.6152	-0.5777	-1.3209	-0.5600	-1.3754	-0.6666
28	-0.0573	1.3158	1.6090	-0.1431	0.8675	0.0628	-0.4740	-0.0730	0.8630	0.6845
29	0.1208	-0.6056	-0.7888	-0.8017	0.6278	-0.9548	0.5855	-0.2976	-0.5131	0.7064
30	-0.2219	1.0921	-0.2898	-0.2364	-0.1780	-1.7905	1.2815	0.2974	1.7206	0.6056
31	0.6643	-1.3687	-0.7661	0.9588	-2.0415	0.4799	0.3664	-0.0505	0.3712	-0.9106
32	0.8555	0.7155	-0.4215	1.8697	-0.2804	0.0841	-0.4957	0.2164	0.6850	-0.4219
33	0.3024	-0.5118	-0.6269	2.1721	0.1277	0.2047	-1.2692	0.9136	1.9701	0.3412
34	0.3332	-0.9168	-1.6046	1.5363	-1.7086	-1.1742	-0.7829	1.4155	-0.2357	1.2955
35	0.8879	0.3489	0.7215	-0.5475	-0.4067	0.4944	-0.0692	-0.8595	0.4499	-0.7855
Etc.	…	…	…	…	…	…	…	…	…	…

Annex 7: Correlated random variables

Scenarios	NIKE	GE	DAI.DE	TCEH)	BMW	DWNI. DE	DTEGY	ORCL	DB	SNY
1	-1.0008	-1.4755	-0.5947	0.5830	-0.5757	-0.9175	-1.4129	-0.1601	0.0663	1.5393
2	1.7887	-0.1856	-0.7774	-0.5270	0.2207	-0.1566	0.5437	2.0177	0.2225	-0.3203
3	-2.0066	0.0821	-0.3162	-0.1318	1.3726	1.6603	-0.3718	0.6456	0.1780	-0.9283
4	0.3961	-0.0014	-0.3026	0.1654	-1.5104	0.9885	-0.9819	-0.8833	-0.0545	1.3627
5	-0.4307	-0.3364	0.4430	0.2983	-0.2619	-0.6952	-0.5045	0.6503	0.5367	1.5563
6	-1.7906	-0.0540	-0.7497	-0.2670	-1.7772	-0.4164	-0.1397	-0.0751	0.2945	1.5264
7	-0.8090	-0.0115	-0.4420	0.2830	0.8193	-0.4340	-0.3100	-0.4301	-1.1628	0.7565
8	1.8169	1.2116	0.5448	0.6901	-0.6435	0.2928	-0.6640	-0.2147	0.5422	-0.0148
9	-0.0443	0.0838	0.5544	-0.2184	-1.3957	0.6043	-0.1758	0.9581	-0.1388	-0.2098
10	1.0969	0.8700	-0.2971	-0.0461	0.6717	0.0904	0.1914	-0.1543	-0.4980	1.1688
11	1.4519	0.7490	-0.8319	1.6125	-0.2227	0.6404	-0.4198	-0.4020	0.0851	-0.7917
12	1.1951	0.7179	1.2114	-0.8354	0.7941	-0.2555	0.4261	0.7350	1.0590	0.5026
13	0.1566	-0.1553	-0.5588	-0.2408	-0.2400	0.5704	0.3839	0.8267	-0.6069	0.9444
14	-1.0809	-1.4002	-1.2361	-1.3682	-0.0706	-0.1097	-0.2870	-0.7921	-0.6110	-0.6517
15	-0.8523	-0.1760	-0.2489	-1.0743	1.0974	-0.1107	0.6776	-0.0867	1.2288	-0.2007
16	0.2887	1.3969	0.1915	-0.9101	-0.3772	-0.0874	-0.1390	1.3974	0.4891	-1.4470
17	1.5981	1.1710	1.0012	-0.0211	1.7474	0.8486	-0.2164	-0.4189	0.1454	0.2521
18	-1.6213	-0.4044	1.9731	-0.7847	1.5074	-0.8485	0.1872	0.2008	-0.1479	-0.6876
19	-0.2982	0.4289	-0.5451	1.4451	-0.2150	-0.0734	-1.5415	-0.8100	0.0769	-1.2258
20	-0.5102	-0.2596	-0.6577	-1.8259	1.1793	-1.2230	0.5965	-0.0662	0.9284	1.5977
21	0.6359	-0.3728	-0.9626	0.0239	0.4583	-0.0954	-0.8609	0.5619	0.1250	1.4135
22	2.4218	1.1561	0.0406	1.0727	0.2461	-0.4364	0.4243	-1.6118	-0.2805	-0.5538
23	0.9732	-0.2170	0.4543	0.9677	0.1706	0.4395	-0.2823	-0.5469	-0.1667	1.0828
24	-0.3663	-1.1598	1.2818	-0.5414	1.5925	1.3147	0.2642	0.5799	0.3158	-0.1344
25	0.0294	-0.0012	0.0618	-1.2571	-0.1631	-0.1337	0.4239	-0.2097	0.9154	0.0395
26	2.7440	1.7813	0.0224	-0.3271	-1.4126	-0.4696	0.1283	0.7500	0.5724	0.3655
27	-1.3426	-0.6713	-1.3002	-1.3161	1.1210	-0.4922	-1.1937	-0.8953	-0.9458	-0.6319
28	0.6113	1.5729	1.4627	-0.2006	0.8471	-0.1836	-0.0899	0.2783	0.6153	0.6489
29	-0.2211	-1.2207	-0.9415	-0.7460	0.5181	-0.7796	0.2786	-0.2892	-0.2743	0.6697
30	1.4616	0.9202	0.4433	-0.3932	0.0461	-1.3678	1.1758	0.7951	1.1643	0.5741
31	0.5945	-0.8752	-0.3201	0.9477	-1.8600	0.5770	0.1915	-0.0337	0.1656	-0.8632
32	1.7304	1.0963	0.1613	1.5315	-0.2286	0.0535	-0.1835	0.3125	0.4090	-0.3999
33	1.4624	0.3013	0.6060	1.7620	0.3438	-0.1242	-0.2376	1.2939	1.3042	0.3235
34	0.9351	-1.1333	-1.0453	1.4876	-1.4262	-1.1900	-0.1402	1.1286	-0.0462	1.2281
35	0.5271	0.3993	0.3854	-0.5013	-0.5152	0.4607	-0.1918	-0.5951	0.2269	-0.7447
Etc.	…	…	…	…	…	…	…	…	…	…

Annex 8: Breakpoints

Rating	AAA	AA+	AA	AA-	A+	A	A-	BBB+	BBB	BBB-	BB+	BB	BB-	B+	B	B-	CCC
AAA	1.646	1.841	1.667	1.793			x										
AA+	-1.283	1.709	1.645	1.783	1.604	1.594											
AA	-1.844	-0.814	1.538	1.773	1.597	1.574	1.668		x	x							
AA-	-2.111	-1.577	-1.044	1.381	1.543	1.559	1.652	1.536									
A+	-2.378	-1.879	-1.528	-0.968	1.193	1.499	1.636	1.524	1.343	1.290							
A	-2.484	-2.016	-2.018	-1.707	-1.063	1.207	1.549	1.502	1.331	1.281				0.931			
A-		-2.206	-2.378	-2.130	-1.813	-1.030	1.113	1.438	1.297	1.245	1.040	0.906					
BBB+		-2.400	-2.716	-2.636	-2.362	-1.757	-1.248	1.039	1.247	1.220	1.027	0.896		0.922			
BBB	x			-2.807	-2.636	-2.130	-1.932	-1.198	0.896	1.147	1.002		1.170			x	
BBB-		x	x	-2.929	-3.195	-2.562	-2.260	-1.905	-1.200	0.791	0.966	0.878	1.158		0.751		
BB+						-2.697	-2.678	-2.137	-1.797	-1.211	0.572	0.815	1.146	0.913	0.739		
BB						-2.759	-2.863	-2.235	-2.062	-1.668	-1.134	0.468	1.134	0.904	0.726		
BB-						-2.834	-2.948	-2.457	-2.370	-2.040	-1.667	-1.213	0.781	0.799	0.714		0.740
B+						-2.929		-2.583	-2.414	-2.232	-1.979	-1.645	-0.868	0.524	0.666	0.951	0.740
B								-2.770	-2.462	-2.342	-2.512	-2.005	-1.520	-1.022	0.322	0.902	0.702
B-									-2.748				-2.010	-1.476	-0.955	0.685	0.595
CCC								-2.863	-2.878	-2.489	x	-2.241	-2.113	-1.858	-1.361	-0.645	0.338
D						x	x	-3.195	-3.090	-2.727		-2.576	-2.175	-2.095	-1.734	-1.274	-0.307

Annex 9: Rating assignments

	NIKE	GE	DAI.DE	TCEHY	BMW	DWNI.DE	DTEGY	ORCL	DB	SNY
Default	AA-	BBB+	BBB+	A+	A+	A-	BBB	A	BBB+	AA
Scenario										
1	A+	BBB	BBB+	A+	A+	A-	BBB-	A-	BBB+	AA
2	AA+	BBB+	BBB+	A+	A+	A-	AA	AA+	BBB+	AA-
3	A	BBB+	BBB+	A+	AA-	A-	BBB	A-	BBB+	AA-
4	AA-	BBB+	BBB+	A+	A	A-	BBB	A-	BBB+	AA-
5	AA-	BBB+	BBB+	A+	A+	A-	BBB	A-	BBB+	AA
6	A	BBB+	BBB+	A+	A	A-	BBB	A-	BBB+	AA-
7	AA-	BBB+	BBB+	A+	A+	A-	BBB	A-	BBB+	AA-
8	AA+	A-	BBB+	A+	A+	A-	BBB	A-	BBB+	AA-
9	AA-	BBB+	BBB+	A+	A	A-	BBB	A-	BBB+	AA-
10	AA-	BBB+	BBB+	A+	A+	A-	AA	A-	BBB+	AA-
11	AA	BBB+	BBB+	AAA	A+	A+	BBB	A-	BBB+	AA-
12	AA-	BBB+	A-	A+	A+	A-	AA	A-	A-	AA-
13	AA-	BBB+	BBB+	A+	A+	A-	AA	A-	BBB+	AA-
14	A+	BBB	BBB	A	A+	BBB+	BBB	A-	BBB+	AA-
15	AA-	BBB+	BBB+	A	A+	A-	AA	A-	A-	AA-
16	AA-	A-	BBB+	A+	A+	A-	BBB	A	BBB+	A+
17	AA	A-	BBB+	A+	AAA	A-	BBB	A-	BBB+	AA-
18	A+	BBB+	AA	A+	AA-	A-	AA	A-	BBB+	AA-
19	AA-	BBB+	BBB+	AA-	A+	A	BBB-	A-	BBB+	A+
20	AA-	BBB+	BBB+	A-	A+	BBB+	AA	A-	BBB+	AA
21	AA-	BBB+	BBB+	A+	A+	A-	BBB	A-	BBB+	AA-
22	AA+	A-	BBB+	A+	A+	A-	AA	BBB+	BBB+	AA-
23	AA-	BBB+	BBB+	A+	A+	A-	BBB	A-	BBB+	AA-
24	AA-	BBB+	A-	A+	AA	A-	AA	A-	BBB+	AA-
25	AA-	BBB+	BBB+	A	A+	BBB+	AA	A-	BBB+	AA-
26	AA+	AA	BBB+	A+	A	A-	AA	A-	BBB+	AA-
27	A+	BBB+	BBB	A	A+	BBB+	BBB	A-	BBB+	AA-
28	AA-	AA	A	A+	A+	A-	BBB	A-	BBB+	AA-
29	AA-	BBB	BBB+	A+	A+	A-	AA	A-	BBB+	AA-
30	AA	BBB+	BBB+	A+	A+	A-	AA	A-	A-	AA-
31	AA-	BBB+	BBB+	A+	A-	A-	AA	A-	BBB+	AA-
32	AA	A-	BBB+	AA-	A+	A	BBB	A-	BBB+	AA-
33	AA	BBB+	BBB+	AAA	A+	AA+	BBB	A	A-	AA-
34	AA-	BBB+	BBB+	AA-	A	A	BBB	A	BBB+	AA-
35	AA-	BBB+	BBB+	A+	A+	A-	BBB	A-	BBB+	AA-
Etc.	…	…	…	…	…	…	…	…	…	…

Annex 10: Values of bonds by rating and number of pieces

	NIKE	GE	DAI.DE	TCEHY	BMW	DWNI.DE	DTEGY	ORCL	DB	SNY
	500	1000	1000	5	1000	1000	100	500	1000	10
1	1,118,969	1,231,891	984,405	1,167,000	1,070,378	1,137,000	1,059,351	1,051,307	1,110,990	1,012,690
2	1,120,237	1,235,114	984,405	1,167,000	1,070,378	1,137,000	1,066,895	1,053,773	1,110,990	1,012,587
3	1,116,119	1,235,114	984,405	1,167,000	1,070,585	1,137,000	1,063,175	1,051,307	1,110,990	1,012,587
4	1,119,754	1,235,114	984,405	1,167,000	1,068,841	1,137,000	1,063,175	1,051,307	1,110,990	1,012,587
5	1,119,754	1,235,114	984,405	1,167,000	1,070,378	1,137,000	1,063,175	1,051,307	1,110,990	1,012,690
6	1,116,119	1,235,114	984,405	1,167,000	1,068,841	1,137,000	1,063,175	1,051,307	1,110,990	1,012,587
7	1,119,754	1,235,114	984,405	1,167,000	1,070,378	1,137,000	1,063,175	1,051,307	1,110,990	1,012,587
8	1,120,237	1,238,886	984,405	1,167,000	1,070,378	1,137,000	1,063,175	1,051,307	1,110,990	1,012,587
9	1,119,754	1,235,114	984,405	1,167,000	1,068,841	1,137,000	1,063,175	1,051,307	1,110,990	1,012,587
10	1,119,754	1,235,114	984,405	1,167,000	1,070,378	1,137,000	1,066,895	1,051,307	1,110,990	1,012,587
11	1,120,195	1,235,114	984,405	1,167,696	1,070,378	1,137,000	1,063,175	1,051,307	1,110,990	1,012,587
12	1,119,754	1,235,114	987,421	1,167,000	1,070,378	1,137,000	1,066,895	1,051,307	1,113,248	1,012,587
13	1,119,754	1,235,114	984,405	1,167,000	1,070,378	1,137,000	1,066,895	1,051,307	1,110,990	1,012,587
14	1,118,969	1,231,891	981,807	1,164,907	1,070,378	1,137,000	1,063,175	1,051,307	1,110,990	1,012,587
15	1,119,754	1,235,114	984,405	1,164,907	1,070,378	1,137,000	1,066,895	1,051,307	1,113,248	1,012,587
16	1,119,754	1,238,886	984,405	1,167,000	1,070,378	1,137,000	1,063,175	1,050,994	1,110,990	1,012,303
17	1,120,195	1,238,886	984,405	1,167,000	1,070,702	1,137,000	1,063,175	1,051,307	1,110,990	1,012,587
18	1,118,969	1,235,114	990,599	1,167,000	1,070,585	1,137,000	1,066,895	1,051,307	1,110,990	1,012,587
19	1,119,754	1,235,114	984,405	1,167,399	1,070,378	1,137,000	1,059,351	1,051,307	1,110,990	1,012,303
20	1,119,754	1,235,114	984,405	1,165,380	1,070,378	1,137,000	1,066,895	1,051,307	1,110,990	1,012,690
21	1,119,754	1,235,114	984,405	1,167,000	1,070,378	1,137,000	1,063,175	1,051,307	1,110,990	1,012,587
22	1,120,237	1,238,886	984,405	1,167,000	1,070,378	1,137,000	1,066,895	1,048,774	1,110,990	1,012,587
23	1,119,754	1,235,114	984,405	1,167,000	1,070,378	1,137,000	1,063,175	1,051,307	1,110,990	1,012,587
24	1,119,754	1,235,114	987,421	1,167,000	1,070,651	1,137,000	1,066,895	1,051,307	1,110,990	1,012,587
25	1,119,754	1,235,114	984,405	1,164,907	1,070,378	1,137,000	1,066,895	1,051,307	1,110,990	1,012,587
26	1,120,237	1,242,976	984,405	1,167,000	1,068,841	1,137,000	1,066,895	1,051,307	1,110,990	1,012,587
27	1,118,969	1,235,114	981,807	1,164,907	1,070,378	1,137,000	1,063,175	1,051,307	1,110,990	1,012,587
28	1,119,754	1,242,976	987,370	1,167,000	1,070,378	1,137,000	1,063,175	1,051,307	1,110,990	1,012,587
29	1,119,754	1,231,891	984,405	1,167,000	1,070,378	1,137,000	1,066,895	1,051,307	1,110,990	1,012,587
30	1,120,195	1,235,114	984,405	1,167,000	1,070,378	1,137,000	1,066,895	1,051,307	1,113,248	1,012,587
31	1,119,754	1,235,114	984,405	1,167,000	1,069,405	1,137,000	1,066,895	1,051,307	1,110,990	1,012,587
32	1,120,195	1,238,886	984,405	1,167,399	1,070,378	1,137,000	1,063,175	1,051,307	1,110,990	1,012,587
33	1,120,195	1,235,114	984,405	1,167,696	1,070,378	1,137,000	1,063,175	1,050,994	1,113,248	1,012,587
34	1,119,754	1,235,114	984,405	1,167,399	1,068,841	1,137,000	1,063,175	1,050,994	1,110,990	1,012,587
35	1,119,754	1,235,114	984,405	1,167,000	1,070,378	1,137,000	1,063,175	1,051,307	1,110,990	1,012,587
Etc.	…	…	…	…	…	…	…	…	…	…

Annex 11: Probability distribution of the portfolio value

Scenario	Values	Frequency	Cumulative frequency	R1	R2
1	10,586,964	1	1	0.00%	0.00%
2	10,600,887	2	3	0.01%	0.01%
3	10,614,810	0	3	0.00%	0.01%
4	10,628,733	0	3	0.00%	0.01%
5	10,642,656	0	3	0.00%	0.01%
6	10,656,579	7	10	0.03%	0.04%
7	10,670,502	10	20	0.04%	0.08%
8	10,684,425	0	20	0.00%	0.08%
9	10,698,348	0	20	0.00%	0.08%
10	10,712,271	0	20	0.00%	0.08%
11	10,726,194	0	20	0.00%	0.08%
12	10,740,117	0	20	0.00%	0.08%
13	10,754,041	0	20	0.00%	0.08%
14	10,767,964	0	20	0.00%	0.08%
15	10,781,887	0	20	0.00%	0.08%
16	10,795,810	1	21	0.00%	0.08%
17	10,809,733	3	24	0.01%	0.10%
18	10,823,656	2	26	0.01%	0.10%
19	10,837,579	0	26	0.00%	0.10%
20	10,851,502	1	27	0.00%	0.11%
21	10,865,425	23	50	0.09%	0.20%
22	10,879,348	103	153	0.41%	0.61%
23	10,893,271	279	432	1.12%	1.73%
24	10,907,194	69	501	0.28%	2.00%
25	10,921,117	24	525	0.10%	2.10%
26	10,935,041	252	777	1.01%	3.11%
27	10,948,964	4287	5064	17.15%	20.26%
28	10,962,887	18770	23834	75.08%	95.34%
29	10,976,810	1166	25000	4.66%	100.00%
30	10,990,733	0	25000	0.00%	100.00%