Credit Risk Measurement under Basel II

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BMI Paper

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Preface

This paper is a compulsory element of the study Business Mathematics and Informatics. During an internship at a financial institution I got interested in the subject of this paper, Credit Risk Measurement under Basel II. The main goal of this paper is that the student learns to do literary research and that the student learns to write a paper in a scientific way. This paper has been the last subject I have done and can be seen as one of the main achievements of 5 years of study.

I hereby want to thank my supervisor Menno Dobber for his time and advice. I enjoyed writing this paper and his way of guiding me through this process has certainly attributed to that! Menno, good luck with writing your PhD thesis.

Koen Munniksma
August 2006

Abstract

In this paper the credit risk measurement under the Basel II Capital Accord is discussed. The Basel II Capital Accord is the successor of the Basel I Capital Accord (1988). The Basel I Capital Accord represented the first step toward risk-based capital adequacy requirements. However, since 1988 the financial world has changed dramatically and there existed a growing need within the financial world for a new capital accord. In 2007 a new capital accord will become operative, and it will improve the Basel I Capital Accord on several aspects.

The Basel II Capital Accord seeks to improve on the existing rules by aligning regulatory capital requirements more closely to the underlying risks that banks face. One of the risk types described in the Capital Accord is credit risk. Banks need to hold capital to cover the credit risk on their credit portfolio. The focus of this paper lies on the analysis of the Internal Ratings Based (IRB) Capital Requirements function for credit risk. On the basis of the work of Merton and Vasicek, the Basel Committee on Banking Supervision (BCBS) decided to adopt the assumptions of a normal distribution for the systematic and idiosyncratic risk factors of a credit portfolio. The model behind the capital requirements function is called an Asymptotic Single Risk Factor (ASRF) model. The Basel Committee had as important requirement that the capital requirements function should be portfolio invariant. Gordy has shown that essentially only ASRF models are portfolio invariant. and therefore the Basel Committee has chosen for an ASRF model. Although the Basel II Capital Accord is a clear improvement of the Basel I Capital Accord, it still has some clear weaknesses. For example, the assumption of portfolio invariance made by the Basel Committee ignores the existence of concentration risk.

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1. Introduction

In recent years the needs for professional skills in the modelling and management of credit risk have rapidly increased and credit risk modelling has become an important topic in the field of finance and banking. While in the past most interests were in the assessments of the individual creditworthiness of an obligor, more recently there is a focus on modelling the risk inherent in the entire banking portfolio. This shift in focus is caused in greater part by the change in the regulatory environment of the banking industry. Banks need to retain capital as a buffer for unexpected losses on their credit portfolio. The level of capital that needs to be retained is determined by the central banks. In 2007 a new capital accord, the Basel II Capital Accord, will become operative. This accord will be the successor of the Basel I accord. The capital accords are named after the place where the Bank for International Settlements (BIS) is settled, namely Basel, Switzerland. The BIS gives recommendations concerning banks and other financial institutes on how to manage capital. The influence and reputation of the Basel Committee on Banking Supervision is of such nature that its recommendations are considered world wide as “best practice”.

Due to these changes in the banking and finance industry the use of risk measures in credit portfolio management has increased dramatically. One of the most used risk measures is Value at Risk (VaR). VaR is used in finance as a technique that uses statistical analysis of historical data to estimate the likelihood that a given portfolio’s losses will exceed a certain amount. There are various methods to calculate VaR and these methods have a large impact on the way a bank manages its credit portfolio. Furthermore VaR is incorporated in the Basel II Capital Accord.

In this paper the reader will be introduced to the economic concepts and mathematical models underlying credit risk measurement under Basel II. The development of credit risk measurement will intensify because of the New Capital Accord and new models and methods will arise to improve risk management. A step is made in the right direction, but the end destination has certainly not been reached!

In Chapters 2 till 4 comprise out of a general discussion of the Bank for International Settlements and the Basel Capital Accords. In Chapter 5 VaR and other financial risk measures are discussed. Thereby a short description is given of the concept of coherent risk measure. In chapter 6 the Basel II approaches for credit risk measurement are broadly discussed. In the final chapter some conclusions are drawn on the limitations of the Basel II Capital accord for credit risk measurement.

2. Bank for International Settlements

The Bank for International Settlements (BIS) was established in 1930. It is the world's oldest international financial institution and remains the centre for international central bank cooperation. The BIS was established in the context of the Young Plan (1930). This plan dealt with the issue of the reparation payments imposed on Germany following the First World War. BIS was to take over the functions previously performed by the Agent General for Reparations in Berlin. These functions include the collection, administration and distribution of the annuities payable as reparations.

The BIS was also created to act as a trustee for the Dawes and Young Loans, international loans issued to finance reparations, and to promote central bank cooperation in general. The functions involving the issue of reparation payments quickly became obsolete. The Bank focused thereby its activities entirely on the cooperation between central banks and other agencies in pursuit of monetary and financial stability.

In the immediate aftermath of the Second World War and until the early 1970s the BIS focus was shifted primarily on implementing and defending the Bretton Woods system. On July 1st 1944, politicians from all 44 allied nations came together in Bretton Woods New Hampshire to construct a new economical system. This system is called the Bretton Woods system. The chief features of the Bretton Woods system were an obligation for each country to adopt a monetary policy that maintained the exchange rate of its currency within a fixed value (plus or minus one percent) in terms of gold. In the face of increasing strain, the system collapsed in 1971, following the United States' suspension of convertibility from dollars to gold.

The central bank cooperation at the BIS has taken place through the regular meetings in Basel of central bank Governors and experts from central banks and other agencies. The main goal of this international cooperation is to prevent liquidity and solvency problems in the financial sector. In 1974 the bankruptcy of the German bank Bankhaus Herstatt almost caused a global financial crisis. This brought the issue of regulatory supervision of internationally active banks to the foreground and resulting in the establishment of the Basel Committee on Banking Supervision (BCBS). The Committee consists of the supervisory authorities and central banks of the G-10 countries (currently 13 countries[*]).

[*] Belgium, Canada, France, Germany, Italy, Japan, Luxemburg, Netherlands, Spain, Sweden, Switzerland, United Kingdom, United States of America

In 1988, the BCBS has proposed guiding principles for the banking industry in the Basel Capital Accord. The Basel Capital Accord was gradually adopted by the central banks. Although the BIS does not occupy itself with the implementation of regulation, its reputation and influence is of such nature that its recommendations are considered as best practise. More recently the issue of financial stability in the wake of economic integration and globalisation has received a lot of attention.

The Basel I capital accord is now widely viewed as outmoded. It is risk insensitive and can easily be circumvented by regulatory arbitrage. Regulatory arbitrage is where a regulated institution takes advantage of the difference between its real risk and the regulatory position. A new capital accord, the Basel II Accord, has been created to cope with this problem. In Table 2.1, a timetable of the development of the regulatory environment and the capital accords is given. The new capital accord promotes greater consistency in the way banks and banking regulators approach risk management. The implementation of the Basel II Accord is expected by 2007 in many of the over 100 countries currently using the Basel I accord. In Chapter 4, the Basel II accord will be discussed in more detail.

Table 2.1 Evolution of the Regulatory Environment

1988	Basel Capital Accord
1996	Market Risk Capital Amendment
1996 – 1998	Ad hoc rules for credit derivatives
Jun. 1999	Consultative Document from Basel Committee
Jan. 2001	Basel Committee proposes New Capital Accord
Nov. 2005	Basel II: International Convergence of Capital Measurement and Capital Standards: A Revised Framework

Apart from fostering monetary policy cooperation, the BIS performs and has performed numerous other functions:

- The BIS has always performed "traditional" banking functions for the central bank community. It has done gold and foreign exchange transactions and employed trustee and agency functions. The BIS was the agent for the European Payments Union (EPU, 1950-58) and has acted as the agent for various European exchange rate arrangements. One of these exchange rate arrangements was the European Monetary System (EMS, 1979-94) which preceded the move to a single currency.
- The BIS has provided or organised emergency financing to support the international monetary system when needed. During the 1931-33 financial crisis, the BIS organised support credits for both the Austrian and German central banks. In the 1960s, the BIS arranged special support credits for the French franc (1968). More recently, the BIS has provided finance in the context of IMF-led stabilisation programmes (Mexico in 1982 and Brazil in 1998).

- The BIS has developed its own research in financial and monetary economics and makes an important contribution to the collection, compilation and dissemination of economic and financial statistics.

3. Basel I Capital Accord

The Basel I Capital Accord represented the first step toward risk-based capital adequacy requirements. The accord was an agreement by the members of the BCBS with respect to minimum regulatory capital for credit risk. Credit risk is the possibility of a loss as a result of a situation that those who owe money to the bank may not fulfil their obligation. Regulatory capital refers to the risk-based capital requirements under the Capital Accord. The purpose of regulatory capital is to ensure adequate resources are available to absorb bank-wide unexpected losses. Under the rules of the Basel I accord, the minimum regulatory capital associated with loans or other cash assets, guarantees, or derivative contract is calculated as:

$$\textit{Regulatory Capital} = \textit{Risk Weight} \times \textit{Exposure} \times 8\% = \textit{Risk-Weighted-Assets} \times 8\%$$

In the above formula the constant 8% is the minimum ratio of regulatory capital to total risk-weighted assets (RWA). This value was determined by the Basel Committee. In the following paragraphs the formula for the calculation of regulatory capital is discussed. At the end of this Chapter the shortcomings of the Basel I Capital Accord are discussed.

Risk Weight

The risk weights reflect the relative credit riskiness across different types of exposures. The Risk Weight for a transaction is determined by characteristics of the obligor. In Table 3.1 the risk weights from the Basel I Capital Accord are given. Roughly speaking, three kinds of obligors can be distinguished: Sovereigns, Banks and Corporates with corresponding risk weights of 0%, 20% and 100%.

Table 3.1 Risk Weights from the Basel I Capital Accord

Obligor	**Risk Weight**
OECD central governments [*]	0%
Domestic public sector entities (excluding central governments)	0%, 10%, 20% or 50% Percentage Set by domestic regulator
OECD banks and regulated firms	20%
Loans fully secured by residential property	50%
Counterparties in derivatives transactions	50%
Public sector corporations; non-OECD banks	100%

[*] Organisation for Economic Co-operation and Development (OECD) is an international organisation of those developed countries that accept the principles of representative democracy and a free market economy.

Exposure

The type of instrument determines the Exposure:

- For fully funded loans or bonds, the exposure is the face amount.
- For unfunded commitments; the exposure is 50% of the commitment for undrawn commitments with maturity over on year and 0% of the commitment for undrawn commitments with maturity less than one year.
- For credit products (e.g. guarantees) the exposure is 100% of the notional value of the contract.
- For derivatives the exposure is determined by the equation: Replacement Costs +(Add-On Percentage × Notional Principal). In Table 3.2 the add-on percentages are given.

Table 3.2 Add-on Percentages for Derivative Contracts under the Basel I Capital Accord

Maturity	Interest Rate	Exchange Rate and Gold	Equity	Precious Metals Except Gold	Other Commodities
One year or less	0.0%	1.0%	6.0%	7.0%	10.0%
More than one year to five years	0.5%	5.0%	8.0%	7.0%	12.0%
More than five years	1.5%	7.5%	10.0%	8.0%	15.0%

Shortcomings of Basel I Capital Accord

In the last part of this Chapter several shortcomings of the Basel I Capital Accord are discussed. Although Basel I helped to stabilize the declining trend in banks' solvency ratios, it suffered from several problems that became increasingly evident over time. The Basel I Capital Accord dates from 1988 and since then the financial world has changed dramatically. It is criticized on generally three grounds:

1. The Basel I Capital Accord provides inconsistent treatment of credit risks. For example, a relatively risky bank in an OECD country requires less regulatory capital than a relatively less risky corporation.
2. The Basel I Capital Accord does not measure risk on a portfolio basis. It does not take account of diversification or concentration and there is no provision for short positions. For example the amount of regulatory capital on a mortgage loan in a portfolio consisting only out of mortgages is the same as when the mortgage loan is part of a portfolio consisting of a variety of loan products.
3. The Basel I Capital Accord provides for no regulatory relief as models and management of capital improve.

4. Basel II Capital Accord

4.1 Introduction

In January 2001 the BCBS released its proposal for a new Accord. This new Accord, the Basel II Capital Accord, is the successor of the Basel I Capital Accord. The Basel II Capital Accord attempts to improve the Basel I Capital Accord in the following points:

- In the Basel II Capital Accord banks are granted a greater flexibility to determine the appropriate level of capital to be held in reserve according to their risk exposure.
- The Basel II Capital Accord focuses on the enhancement of the stability and reliability of the international financial system.
- The Basel II Capital Accord stimulates the improvement of risk management.

In the remainder of this chapter the Basel II accord is described.

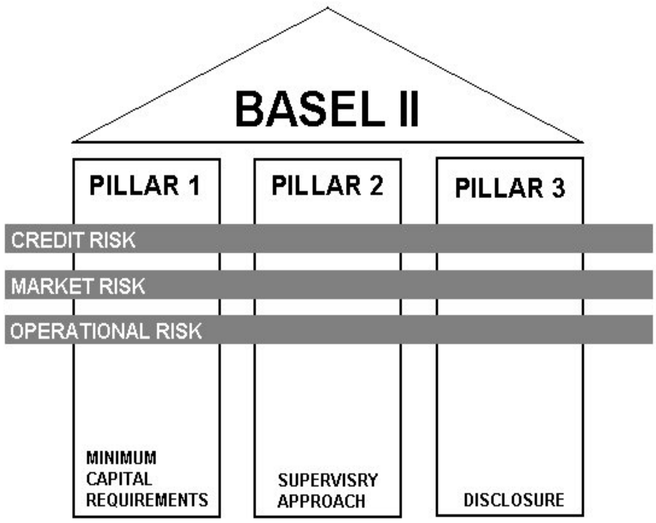
4.2 The three pillars of the new Accord

The Basel I Capital Accord focused only on minimum regulatory capital requirements. The Basel II Capital Accord broadens this focus by describing the supervisory process in the Basel II Capital Accord by "three pillars":

- Pillar 1 - Minimal regulatory capital requirements.
- Pillar 2 - Supervisory review of capital adequacy.
- Pillar 3 - Market discipline and disclosure.

The focus of the paper lies in the measurement of credit risk, which is extensively described in Pillar 1. Below the contents of the Pillars are shortly discussed and in Chapter 6 the credit risk measurement is broadly discussed.

Figure 4.1 The Three Pillars of Basel II



Pillar 1- Minimum Regulatory Capital Requirements

For the first pillar of the Basel II Capital Accord the Basel Committee proposed capital requirements associated with three categories of risk:

1. *Market Risk*

   Market Risk is the risk that the value of an investment will decrease due to moves in market factors. Within the Basel II Capital Accord, there are two methods to measure market risk: The Standardized Approach and the Internal Models Approach.

2. *Operational Risk*

   Operational risk is defined in the Basel II as the risk of loss resulting from inadequate or failed internal processes, people and systems, or from external events. Three different methods can be used to measure operational risk: The Basic Indicator Approach, the Standardized Approach and the Advanced Measurement Approach.

3. *Credit Risk*

   Credit risk is the possibility of a loss as a result of a situation that those who owe money to the bank may not fulfil their obligation. The following methods can be used to determine credit risk: The Standardized Approach, The Foundation Internal Rating Based Approach and the Advanced Rating Based Approach. The Standardized Approach provides improved risk sensitivity compared to Basel I. The two IRB approaches, which rely on banks' own internal risk ratings, are considerably more risk sensitive.

Pillar 2 - Supervisory review of capital adequacy

The second pillar of Basel II is a supervisory review of capital adequacy. The second pillar notes that national supervisors must ensure that banks develop an internal capital assessment process and set capital targets consistent with their risk profiles. Furthermore it encourages the bank's management to develop risk management techniques and their use within capital management. The supervisors are responsible for evaluating how well banks are assessing their capital adequacy needs relative to their risks. Internal processes of the bank are subject to supervisory review and intervention. In the Netherlands the role of supervisor is fulfilled by the Dutch Central Bank, "De Nederlandsche Bank" (DNB).

Pillar 3 – Market discipline and disclosure

The third pillar of the Basel II Capital Accord is about market discipline and disclosure. The main goal of this pillar is to promote the development of financial reporting about risks. In this way market participants can get a better understanding of banks risks profiles and the adequacy of their capital position by disclosure. Pillar 3 in the Basel II Capital Accord sets out disclosure requirements and recommendations in several areas. These requirements apply to all banks and when a bank cannot meet these requirements it can be constrained in the way it manages capital. For example the bank may not use any of the advanced techniques under Pillar 1.

5. Value at Risk and other financial risk measures

5.1 Introduction

VaR expresses the expected maximum loss that may be incurred over a defined time horizon and within a specified confidence interval. Value at Risk (VaR) is one of the most popular tools used in financial risk measurement. The concept of VaR has now been incorporated in the Basel II Capital Accord. Understanding VaR and its application in risk management is essential for understanding the Basel II Capital Accord. In this Chapter, first some methods for the computation of VaR are described. Then some other risk measures like Expected Loss and Expected Shortfall and the limitations of VaR are discussed.

5.2 VaR Approaches

A variety of approaches exist for estimating Value At Risk. The most common assumption in these models is that historical data is the best estimator for future changes. However, every approach has besides this assumption its own specific set of assumptions. The following models can be distinguished:

1. *The Variance-Covariance (VCV) Approach:*
   The VCV approach assumes that risk factor returns are always (jointly) normally distributed and that the change in portfolio value is linearly dependent on all risk factor return.
2. *The Historical Simulation (HS) Approach*:
   The HS approach assumes that asset returns in the future will have the same distribution as they had in the past.
3. *Monte Carlo Simulation (MCS) Approach:*
   In the MCS approach future asset returns are simulated.

In the following paragraphs these methods are discussed in more detail.

<u>Variance-Covariance model</u>

The Variance-Covariance method is based on the following two assumptions:

1. The changes in the value of the portfolio are linearly dependent on all the changes in the value of the assets.
2. The asset returns are jointly normally distributed

In order to measure the portfolio's volatility, a covariance matrix must be estimated in advance. If a portfolio consists of N assets, the portfolio return is a linear combination of the returns on the underlying assets. The VaR over the portfolio is then calculated in the following way:

$VaR_P = \alpha \times \sigma_P \times P_0$

With,

P_0 = Portfolio Value; the sum of all asset values,

P_i = Value of asset I,

w_i = P_i / P_0 ; the relative weight of asset i with respect to the total portfolio,

w = column vector of weights; $w = \{w_1, w_2, w_3, \ldots, w_N\}$,

R = column vector of the rate of return; every asset of the portfolio has a different rate of return,

∑ = covariance matrix (mentioned above),

R_P = $w^T R$,

σ_P = $\sqrt{w^T \sum w}$, the standard deviation of the portfolio,

α = the chosen VaR-percentile. Where an α of 1,96 and 2,58 respectively indicating a VaR-percentile of 95% and 99%.

Advantages:

- The methodology is based on well-known techniques.
- If input variables such as the covariance matrix are known, VaR calculation can be done in a simple Excel spreadsheet.
- VaR calculation is fast with the covariance variance method because it is not simulation-based but analytical.

Disadvantages:

- The portfolio is composed of assets whose changes are linear.
- The assumption that the asset returns are normally distributed is rarely true (parametric).

Historical Simulation

In the historical simulation approach the distribution of future shifts in risk factors of a portfolio is treated in the same way as prior-period distributions of shifts. This means that past shifts are used to revalue the portfolio and simulate its profits and losses. VaR is then obtained by reading the relevant quantile (e.g. 95% quantile or 99% quantile) off the histogram of simulated returns.

Advantages:

- The historical simulation method is very simple to implement.
- It is non-parametric; i.e. it does not assume a normal distribution of asset returns

Disadvantages:

- The method requires a large database containing historical data; the quality of data management must be high.
- The method is computationally intensive.

Monte Carlo Simulation

Estimating VaR via Monte Carlo simulations is similar in some respects to applying the historical and the parametric methods. First, the joint distribution of risk factors is specified and used to generate a large number of risk-factor variation scenarios. These scenarios are then used to compute the hypothetical results of the portfolio. Last, VaR is determined in the same way as in the historical simulation approach but on the basis of the simulated sample.

Advantages:

- The Monte Carlo simulation approach can easily be adjusted to economic forecasts.
- It is just as the historical simulation method non-parametric.

Disadvantages:

- The approach requires a lot of computational power
- The number of simulation runs needed to obtain an acceptable degree of accuracy is high

5.3 Financial Risk Measures

In this Section some other financial risk measures besides Value at Risk are discussed. Furthermore the concept of 'coherent risk measure' is explained. A financial risk measure is a metric measuring the uncertainty of portfolio loss. Several risk measures are defined for portfolio loss. The most important risk measures are:

- *Expected Loss* (EL): The mean of the portfolio loss distribution.
- *Unexpected Loss* (UL): The standard deviation of the portfolio loss distribution
- *Value At Risk* (VaR) or *Economic Capital* (EC); where EC is defined as the 99,95% VaR - EL
- *Expected Shortfall* or *Conditional Value at Risk* (ES or CvaR): CVaR or ES is the portfolio loss one expects to suffer, given that the portfolio loss is equal to or larger than its VaR.

In the literature researchers have extensively criticized the use of VaR as a measure of risk. For example, Artzner, Delbaen, Eber and Heath (1999) show that VaR is not a 'coherent' measure of risk. A coherent risk measure needs to satisfy five properties. If A en B denote portfolios, then f is said to be a coherent risk measure if:

- Translation invariance: $f(A + \alpha r) = f(A) - r$, where r is a reference risk free investment
- Sub-additivity: $f(A+B) \leq f(A) + f(B)$

- Positive homogeneity: for all $\lambda \geq 0$, $f(\lambda A) = \lambda f(A)$
- Monotoneity: if $A \leq B$ then $f(A) \leq f(B)$
- Relevance: if $A \neq 0$ then $f(A) > 0$

The risk measures UL and VaR are not coherent risk measures. UL is not monotonous and VaR does not satisfy the sub-additivity property, because of that the following situation may arise: VaR(A+B) > VaR(A) + VaR(B). This means that in this situation diversification has no effect. Expected Shortfall is on the other hand a coherent risk measure and therefore guarantees that the portfolio diversification is always positive. Although VaR is now widely used in financial risk measurement, it is probably not the risk measure of the future!

6. Basel credit risk approaches

6.1 Introduction

The way banks can improve their credit risk management is not determined in the Basel II Capital Accord. Banks have the choice between three methods for arranging their credit risk management:

1. The Standardized Approach (SA)
2. Foundation Internal Ratings Based Approach (F-IRB)
3. Advanced Internal Ratings Based Approach (A-IRB)

Table 6.1 General comparison between the three approaches

Approach	The Standardized Approach	Foundation IRB Approach	Advanced IRB Approach
Complexity	Low	Medium	High
Accuracy	Low	Medium	High
Capital Charge	High	Medium	Low

There is a big difference between the standardized approach and the two IRB approaches. The two IRB approaches make use of external credit agencies (*) , while the SA is more an extension of the Basel I system. The SA is the approach that banks should minimally use. The IRB approaches make use of internal credit models. Banks can only use these two approaches if their data management is of high level. A data history of 5 years for various products and clients is necessary. In Table 6.1 a summary is given of the differences between the three approaches.

The migration from the SA to the IRB approaches is complex, claims a lot of effort from staff and requires more computer hardware capacity. However, it can be concluded that the increase in labour intensity caused by an IRB approach is accompanied with high savings. In the remainder of this Chapter the Approaches are discussed in more detail. First the Standardized Approach is discussed and then the IRB approaches are discussed.

6.2 The Standardized Approach

The standardized approach is similar to the approach in the Basel I Capital Accord in that the risk weights are determined by the category of borrower (sovereign, bank, corporate). The SA is in principal the same as the current approach. However, it is more risk sensitive than the current approach. Every asset class or derivative is assigned a risk weight. These risk weights are based on the external credit ratings provided by the credit rating agencies.

(*) Moody's, S&P and Fitch are the most well-known credit rating agencies

Table 6.2 provides the risk weights proposed by the Basel Committee. The Standardized Approach is clearly an improvement on the Basel I Capital Accord:

- The SA eliminates the OECD club preference in the Basel I Capital Accord.
- The SA provides greater differentiation for corporate credits.
- Higher risk categories (150%) are introduced in the SA.
- The SA contains the option to allow higher risk weights for equities.

Table 6.2 Risk Weight in Standardized Approach of Basel II Capital Accord

Rating of Entity	**Risk Weights**		
	Sovereigns	**Banks**	**Corporates**
AAA to AA-	0%	20%	20%
A+ to A-	20%	50%	50%
BBB+ to BBB-	50%	50%	100%
BB+ to BB-	100%	100%	100%
B+ to B-	100%	100%	100%
Below B-	150%	150%	150%
Unrated	100%	50%	100%

For Residential Mortgages the risk weights are set to 35% and for all other retail loans the risk weights are 75%. The following equation is used to calculate the minimum regulatory capital for credit risk and is the same as in the Basel I Capital Accord:

$$Regulatory\ Capital = Risk\ Weight \times Exposure \times 8\%$$

6.3 Internal Ratings Based Approach

The SA was targeted at banks desiring a simplified capital framework. For the more sophisticated banks the Basel Committee proposed two IRB approaches, foundation and advanced. The difference between these approaches is subtle.

6.3.1 Minimal Regulatory Capital Requirements (K)

The following formula is used to calculate the minimal capital requirements, *K*, under the Internal Ratings Based Approach:

$$K = \left[LGD \times N\left[\frac{1}{\sqrt{1-R}} \times G(PD) + \sqrt{\frac{R}{1-R}} \times G(0.999) \right] - PD \times LGD \right] \times \left(\frac{1 + (M - 2.5) \times b(PD)}{1 - 1.5 \times b(PD)} \right)$$

Where,

R = Asset Correlation; the correlation between an individual loan and the global state of the world economy,

N[…] = the cumulative distribution for a standard normal variable,

G[…] = the inverse cumulative distribution for a standard normal variable,
LGD = Loss Given Default,
PD = Probability of Default,
M = Maturity of the loan,
b(PD) = Smoothed regression maturity function. The slope of the adjustment function with respect to M decreases as the PD increases.

In Section 6.4 the parameters of the capital requirements formula are further explained. For calculating the regulatory capital one now simply multiplies the capital requirements with the exposure at default:
Regulatory Capital = K x EAD

6.3.2 Economic Concepts behind the IRB Capital Requirements Function

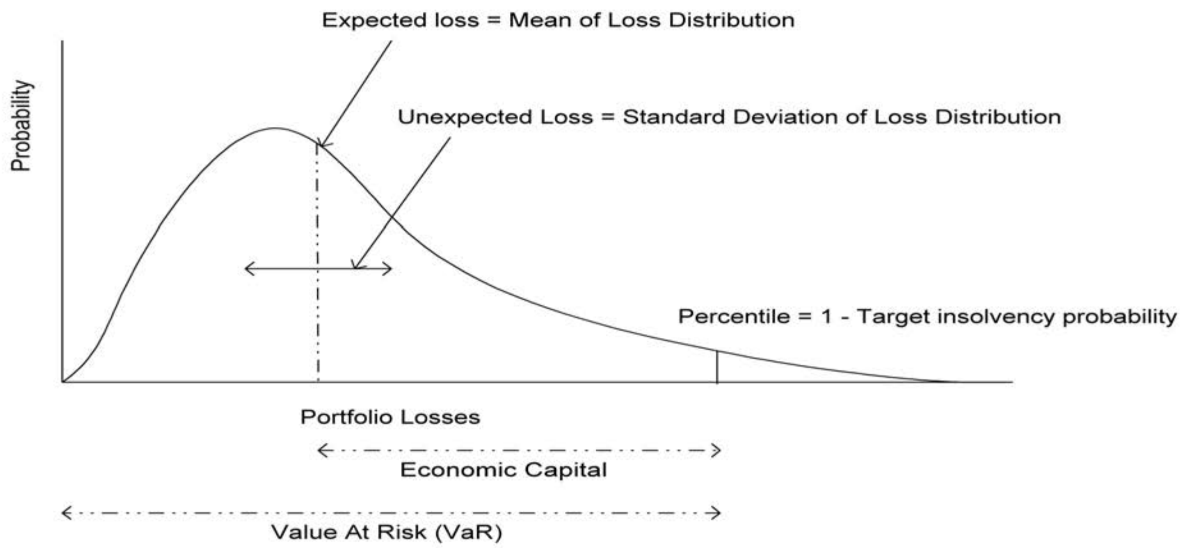
The IRB risk weight equation seems arbitrary and mechanical at first sight. However, there are some important concepts embedded in this equation. By means of Figure 6.1 these economic concepts are discussed. The curve in the figure below describes the likelihood of losses of a certain magnitude. The curve represents the probability density function of a portfolio loss.

Expected Loss (EL) is the mean of the loss distribution (Figure 6.1). The EL is defined as the average level of credit losses a financial institution can reasonably expect to experience. Note that, in contrast to a normal distribution, the mean is not at the centre of the distribution but rather is right of the peak. That occurs because the typical loss distribution of a credit portfolio is asymmetric. It has a long right-hand tail. Financial institutions view EL as a cost component of doing business. EL is managed by financial institutions in a number of ways, including through the pricing of credit exposures and through provisioning.

Unexpected Loss (UL) is the standard deviation of the loss distribution. In contrast to EL, UL is a risk associated with being in the business, rather than a cost of doing business. One of the functions of bank capital is to provide a buffer to protect a bank's debt holders against losses that exceed expected levels. Banks often have an incentive to minimise the capital they hold. Reducing capital frees up economic resources that can be directed to profitable investments. However, if a bank holds less capital, its chance that is will not be able to meet its own debt obligations will increase.

Economic Capital (EC) is a risk measure that can be viewed, as the amount of capital the bank needs to retain to cope with unexpected loan losses. The more risky the assets, the more capital will be required to support them. The main difference between EC en **Regulatory Capital (RC)** is that RC is the minimal capital required by the regulator (Basel II), whereas economic capital is the capital level bank shareholders would choose in absence of capital regulation. The **target insolvency rate** of a financial institution determines the amount of EC a bank needs to retain. Many large commercial banks are using a target insolvency rate of 0,03%. The target insolvency rate is directly linked with the credit rating of the financial institution. Looking at historical one-year default rates, the probability of default for a financial institution rated AA is 0,03%.

Figure 6.1 Portfolio Loss Distribution



The IRB approach focuses on the frequency of bank insolvencies arising from credit losses that supervisors are willing to accept. It is possible to estimate the amount of loss which will be exceeded with a predefined probability by means of a stochastic credit portfolio model. The area under the right hand site of the curve is the likelihood that a bank will not be able to meet its own credit obligations by its profits and capital. The **percentile** or **confidence level** is then defined as 100% minus this likelihood and the corresponding threshold is called the **Value At Risk (VaR)**.

6.4 Interpreting the IRB Capital Requirements function

In the Section 6.3 the IRB capital requirements function has been introduced. In this section the capital requirements function is explained in detail. First, the model behind the capital requirements function is discussed. Then, the function is decomposed into several parts, and every part is broadly discussed. The Basel II IRB approach is built on the following credit risk drivers.

- Probability of Default (PD): The Probability of Default quantifies the risk that the obligor will default in the coming 12 months.
- Loss Given Default (LGD): LGD is defined as the economic loss that the Bank has suffered or expects to suffer on a credit facility upon which counter party defaults. It is expressed as a percentage of the calculated or estimated expected EAD.
- Exposure at Default (EAD): The Exposure at Default is the exposure of the bank at the moment that the obligor goes into default.
- Maturity (M): The maturity of a loan expresses the amount of time until the loan is fully due and payable.

Then, the Expected Loss can be written as:

$$EL = PD \times EAD \times LGD$$

In the Basel I Capital Accord (Chapter 3) and the Standardized Approach of Basel II (Section 6.2) these main drivers for credit risk are not incorporated in the calculation of regulatory capital. However in the IRB approach they play a central role. In the following paragraph is explained on what mathematical basis the capital requirements function has been developed.

The model behind the Capital Requirements function

The Basel Capital Requirements function used for the derivation of supervisory capital charges are based on a specific model developed by BCBS. An important restriction was made to fit supervisory needs; The capital required for any given loan should only depend on the risk of that loan and must not depend on the portfolio it is added to. In other words; the model underlying the Basel Capital Requirements function should be portfolio invariant.

Gordy (2003) has shown that essentially only so called Asymptotic Single Risk Factors (ASRF) models are portfolio invariant. ASFR models are derived from “traditional” credit portfolio models by the law of large numbers. When a portfolio consists of a large number of relatively small exposures, idiosyncratic risks associated with individual exposures tend to cancel out one-another. Systematic risks that affect many exposures have than only an effect on portfolio losses. The systematic risks that affect all borrowers to a certain degree (e.g. industry and region risks) are modelled in the ASFR model by one systematic risk factor. Banks are encouraged to use other credit risk models to fit their internal risk management needs.

It is possible to estimate the sum of the expected and unexpected losses associated with each credit exposure. This is accomplished by calculating the **conditional expected loss (CEL)** for an exposure given an appropriately conservative value of the single systematic risk factor. The CEL is in the ASRF model expressed as the product of a **conditional PD** and a **downturn LGD**. The conditional PDs are derived from bank-reported average PDs, which reflect expected default rates under normal business conditions, using a supervisory mapping function. The downturn LGD reflects the LGD under economic downturn conditions. During cyclical economic downturns the LGDs are higher than during "average" economic conditions. Adding up the total economic resources (provisions and capital) that a bank must hold to cover all its exposures conditional expected losses, will lead to a portfolio-wide VaR. The mapping function used to derive conditional PDs from average PDs is derived from an adaptation of Merton's model to credit portfolios. According to the Merton Model, borrowers default if they cannot completely meet their obligations at a fixed assessment horizon of one year because the value of their assets is lower than the due amount. Vasicek (2002) showed that under certain conditions the Merton Model can naturally be extended to a specific ASRF credit portfolio model. On the basis of the work of Merton and Vasicek, the BCBS decided to adopt the assumptions of a normal distribution for the systematic and idiosyncratic risk factors.

Downturn LGD

The BCBS determined that given the evolving nature of bank practices in the area of LGD quantification, it would be inappropriate to apply a single supervisory LGD mapping function similar to the PD mapping function. In the advanced IRB approaches banks are required to estimate their own downturn LGDs. These LGDs should reflect the fact that during economic downturn conditions the LGD is higher than during average business conditions.

Figure 6.2 Decomposition of the Capital Requirements Formula

conditional PD

Expected Loss

$$\textit{Capital Requirements(K)} = \left[LGD \times N\left[\frac{1}{\sqrt{1-R}} \times G(PD) + \sqrt{\frac{R}{1-R}} \times G(0.999) \right] - PD \times LGD \right] \times \left(\frac{1 + (M - 2.5) \times b(PD)}{1 - 1.5 \times b(PD)} \right)$$

Conditional Expected Loss or Value At Risk

Maturity adjustment

average PD

As can be seen in Figure 6.2 the capital requirements formula can roughly be viewed as subtracting the conditional expected loss with the expected loss and than multiply this difference with a maturity factor. In the next paragraph the asset correlations (R) are described in detail.

Asset Correlations

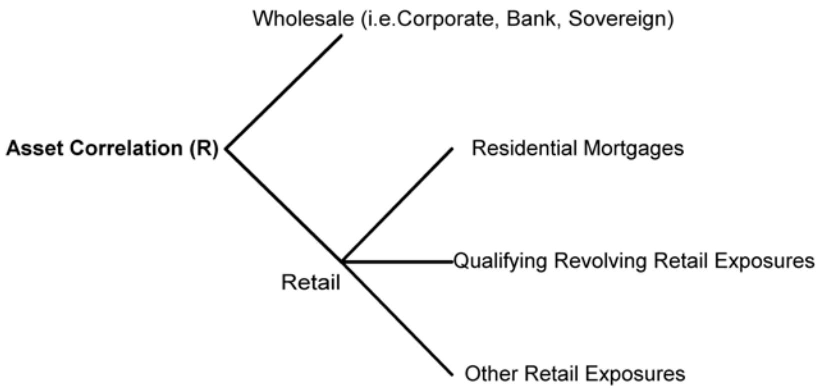
The asset correlations show how the asset value of one borrower depends on the asset value of another borrower. In other words it could be described as the dependence of the asset value of a borrower on the general state of the economy. In this way all borrowers are linked to each other by this single risk factor. The asset correlations are asset class dependent because different borrowers show different degrees of dependency on the overall economy.

The asset correlations of the capital requirements formula for corporate, bank and sovereign exposures have been derived by analysis of data sets from G10 supervisors. The analysis of this data has revealed two systematic dependencies:

1. Asset correlations decrease with increasing PDs: The higher the PD the higher the idiosyncratic risk of a borrower.
2. Asset correlations increase with firm size: Idiosyncratic risks are higher for smaller firms.

The asset correlation functions used in the Basel capital requirements functions incorporate both dependencies. The asset correlations are dependent on the type of asset class. In Figure 6.3, a schema is given for the main type of asset classes. As can be seen in the figure, an essential difference is made between corporate lending and retail or consumer lending.

Figure 6.3 Asset Correlations for different type of Assets



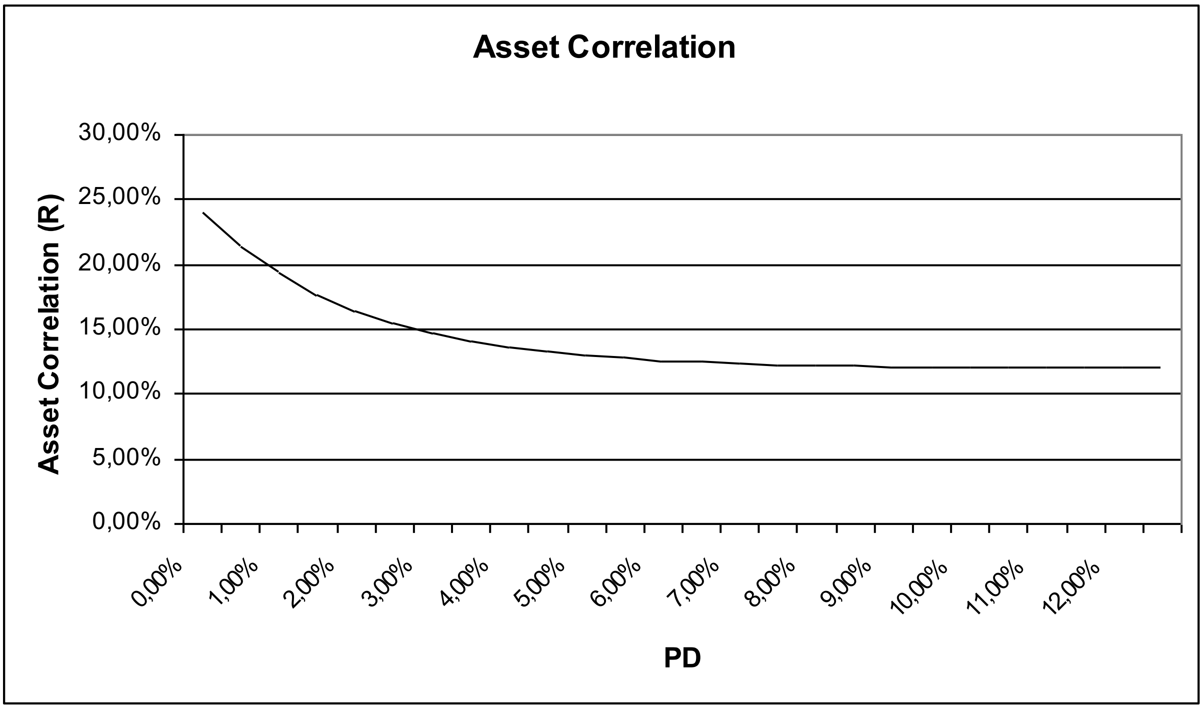
Wholesale (Corporates, Banks and Sovereigns) Asset Correlation

The asset correlation for wholesale exposures is given by the following formula:

$$\textit{Asset Correlation (R)} = 0.12 \times \frac{\left(1\text{-}e^{(-50\times PD)}\right)}{\left(1\text{-}e^{-50}\right)} + 0.24 \times \left(1 - \frac{\left(1 - e^{(-50\times PD)}\right)}{\left(1 - e^{-50}\right)}\right)$$

The asset correlation function is built on two limit correlations of 12% and 24% for respectively very high and very low PDs. The correlations between these limits are modelled by an exponential weighting function. This function is in line with the found dependencies: the asset correlation decreases with increasing PD and (in the case of SMEs) the asset correlation increases with increasing firm size. In Figure 6.4 the asset correlation is graphically displayed.

Figure 6.4 Corporate, Sovereign and Bank Asset Correlation



Firm Size Adjustment for SMEs

For SMEs the asset correlation is calculated slightly different than the asset correlation for wholesale exposures. A firm size adjustment is incorporated in the SME asset correlation formula:

$$\textit{Asset Correlation (R)} = 0.12 \times \frac{\left(1\text{-}e^{(-50\times PD)}\right)}{\left(1\text{-}e^{-50}\right)} + 0.24 \times \left(1 - \frac{\left(1 - e^{(-50\times PD)}\right)}{\left(1 - e^{-50}\right)}\right) - 0.04 \times \left(1 - \frac{(S-5)}{45}\right),$$

Where,

S = Firm size measured as annual sales and 5m $\leq$ S $\leq$ 50m

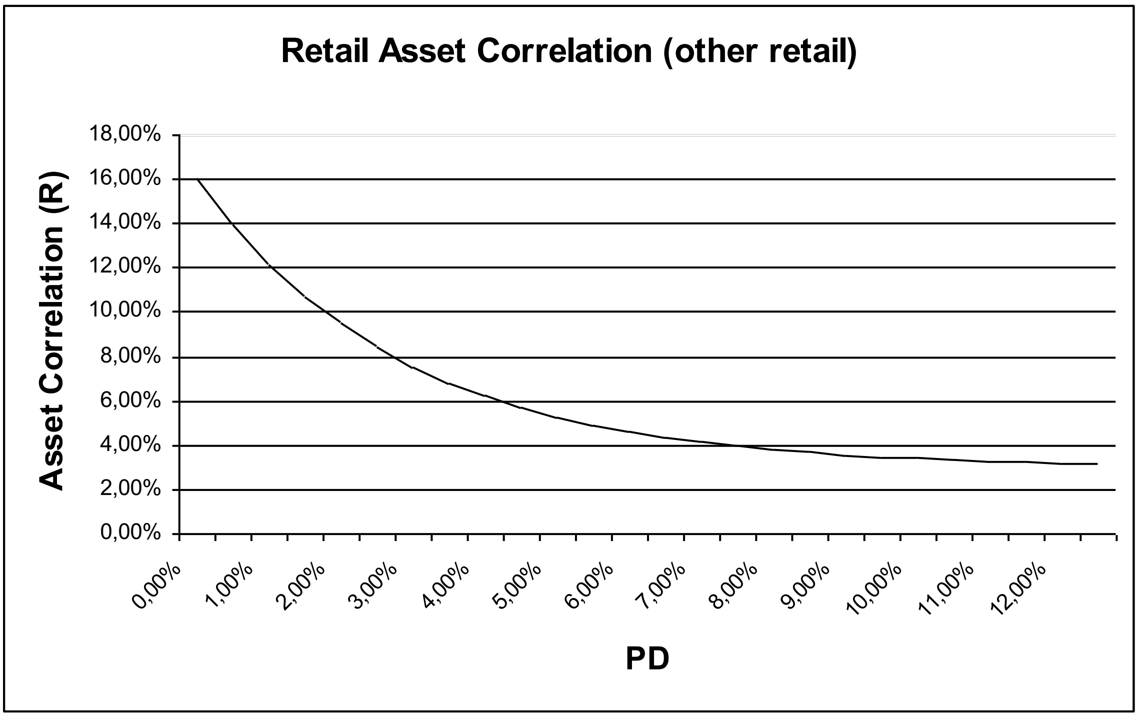
The linear size adjustment added at the end of the formula affects borrowers with annual sales between 5 and 50 million. For borrowers with annual sales above 50 million the firm size adjustment becomes 0 and for borrowers with annual sales lower than 5 million the firm size adjustment is 0.04.

Retail Asset Correlation

The asset correlation assumptions are different for retail exposures than for corporate exposures. The difference relates to the actual calibration of the asset correlation curves. For retail exposure the curves have been derived from economic capital figures from large internationally active banks and from historical loss data from supervisory databases fo the G10 countries. A consequence of this derivation of the retail asset correlations is that for determining the capital requirements for retail exposures the maturity adjusment are not applied. This is because the economic capital data and the supervisory loss data implicity contain the maturity effects.

- Residential Mortgages: *Asset Correlation (R)* = 0.15
- Qualifying Revolving Retail Exposures: *Asset Correlation (R)* = 0.04
- Other Retail Exposures: $Asset\ Correlation\ (R) = 0.03 \times \frac{\left(1\text{-}e^{(-35 \times PD)}\right)}{\left(1\text{-}e^{-35}\right)} + 0.16 \times \left(1 - \frac{\left(1 - e^{(-35 \times PD)}\right)}{\left(1 - e^{-35}\right)}\right)$

Figure 6.5 Other Retail Asset Correlation



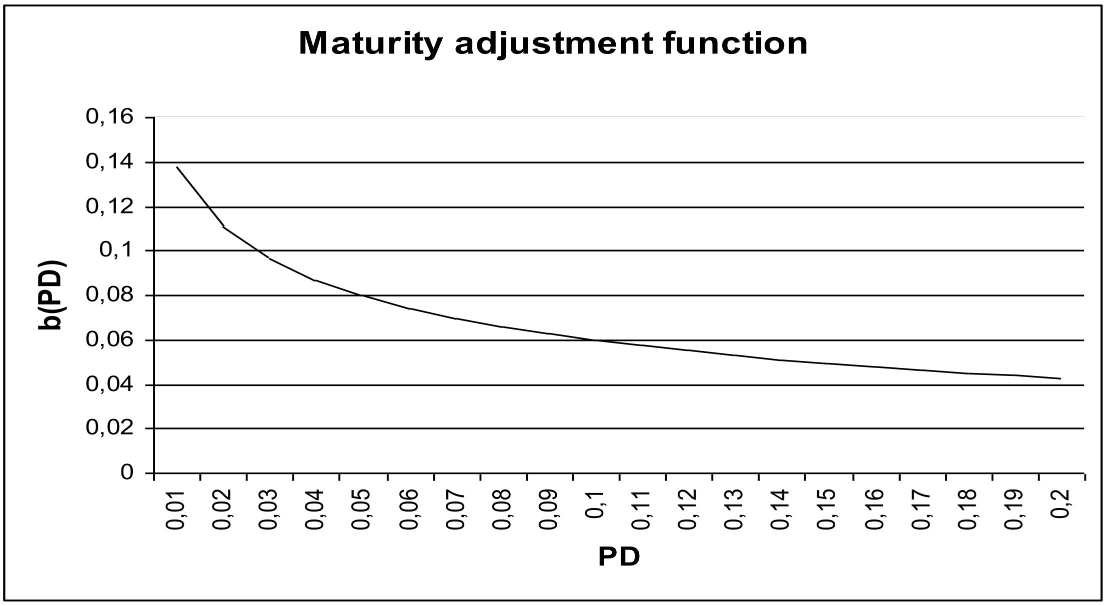
In comparison with Figure 6.4 it can be seen that the asset correlation for other retail exposures declines slower than the asset correlation for corporate exposures when PD increases. This can be explained by the fact that the pace in which the asset correlation function decreases is determined by the so-called "k-factor". For corporate exposures this k-factor is set to 50 and for other retail exposures this k-factor is set to 35. In the following paragraph the last part of the capital requirements function is discussed, namely the maturity adjustment.

Maturity Adjustment

The capital requirements should increase with maturity. Both intuition and empirical evidence indicate that long-term credits are riskier than short-term credits. The form of the Basel maturity adjustments has been derived by applying a specific (mark-to-market) credit risk model. The Basel maturity adjustment function was chosen in such a way that the adjustments are linear and increasing in the maturity M. Furthermore the slope of the adjustment function with respect to Maturity (M) decreases as the PD increases, which can be clearly seen in Figure 6.6. For a maturity of one year the function yields one. The smoothed regression maturity adjustment function looks as follows:

$$b(PD) = (0.11852 - 0.05478 \times \log(PD))^2$$

Figure 6.6 Smoothed regression maturity adjustment



The "full" maturity adjustment that is incorporated in the capital requirements function is as follows:

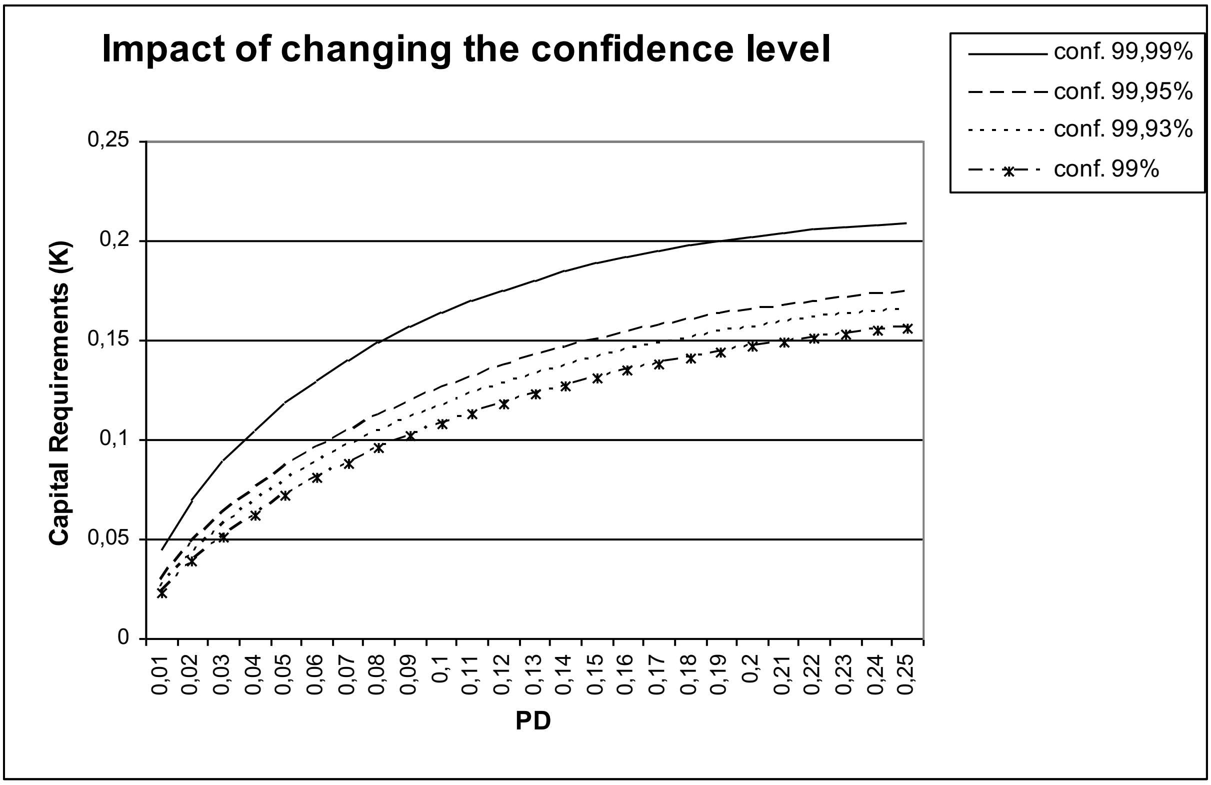
$$\left(\frac{1 + (M - 2.5) \times b(PD)}{1 - 1.5 \times b(PD)}\right)$$

The maturity adjustment is introduced in the formula to reflect the potential credit quality deterioration of loans with longer maturities. The average portfolio effective maturity is set by the Basel Committee at 2.5 years. In the last paragraph of this Section the confidence level that is set by the supervisory authorities is discussed.

Determination of the confidence level

The confidence level is set by the supervisory authorities at 99,9%. It was first set to 99,5% but a higher confidence level was chosen to protect against model uncertainties as well as estimation errors occurring from the PD, LGD and EAD estimation by banks. This confidence level is incorporated in the capital requirements formula by the term G(0.999). In Figure 6.7 can be seen that changing the confidence level from 99,95% to 99,99% has had a big effect on the capital requirements function.

Figure 6.7 Impact of changing the confidence level



In the last Section of this Chapter the differences between the two IRB approaches are discussed.

6.5 Differences between the Foundation and Advanced IRB approaches

The main difference between the foundation and advanced IRB approaches lies in the definition of the input variables. Both approaches rely on banks' PD estimates, but banks' internal estimates of LGD, EAD and loan maturity are only taken account of in the advanced IRB approach. In Table 6.3 these differences are summarized.

Although banks rely on their own PD estimates, they are obliged to use a minimum probability of default of 0.03 percent PD. The transition from an Foundation IRB status to an Advanced IRB status can only be made if the internal risk measurement systems and data management systems are of high quality.

Table 6.3 Difference between determinations of Risk Weights

Determinants of Risk Weights	Foundation	Advanced
Probability of Default (PD)	Bank determines	Bank determines
Loss Given Default (LGD)	Supervisor determines (*)	Bank determines
Exposure At Default (EAD)	Supervisor determines	Bank determines
Maturity (M)	-	Maturity adjustment

(*) DNB determines the LGD and EAD if the bank is located in the Netherlands

Conclusion

In this paper, the credit risk measurement under the Basel II Capital Accord was discussed. First a general introduction was given of the Basel II Capital Accord and then the treatment of credit risk under this new capital accord was discussed in more detail. Below, some conclusions are drawn with respect to credit risk measurement and Basel II.

The main goal of the Basel II Capital Accord is to achieve more tractability and uniformity in the banking world. Therefore, the Basel II Capital Accord is based on some of the same risk measurement concepts as in the economic capital models that more sophisticated banks use internally. However, in its goal of achieving tractability and uniformity are a number of supervisory parameters and simplifying assumptions embedded. The structure of the Basel II Capital Accord is therefore inevetibly different from the internal structure of banks' economic capital models. Therefore, It is important to look for cases in which the Basel II measures are more conservative than a bank's economic model, which might create potential incentives for banks to engage in new forms of regulatory capital arbitrage.

One of the most important assumptions of the Basel II Capital Accord is that the bank's portfolio is well diversified and does not contain any significant concentrations of individual borrowers. Given this assumption the IRB Capital Requirements functions is not designed to be sensitive to variations in concentration risk across banks. The underlying risk of a bank's portfolio can therefore not be fully reflected in the IRB charges. Take for example a portfolio that is highly concentrated in a particular geographic market. The correlation between these assets in the portfolio is for sure higher than the correlation values provided by Basel II. Although the BCBS had proposed a granularity adjustment to address single-borrower concentrations, it dropped this proposal later on. The IRB capital requirements function is therefore insensitive to single-borrower concentrations and the total amount of regulatory capital is linear dependent on the EAD. If now two loans have the same risk profile (PD, LGD and M), but their EAD is different, they still get the same outcome of the IRB Capital Requirements function. Therefore, it can be concluded that the credit risk of a loan can only be measured accurately if concentration risk is taken into account. In the future, this risk must be included in the calculation of regulatory capital, if we want to bring credit risk measurement to a higher level.

Finally, it is for a bank important to explore it's assumptions around correlation within and across different credit portfolio's. A related issue is the way a bank reflects the potential risk posed by concentrations in certain type of exposures. For a bank risk and data management have become a vital part of their business. It has been shown by several impact studies that achieving a high level of risk and data management and thereby earning the A-IRB status leads to a decrease in the minimal regulatory capital requirements. The Basel II Capital Accord is definitely a step forward, but for achieving a financial world without regulatory arbitrage several steps surely still need to be made!

Abbreviations

A-IRB	= Advanced Internal Ratings Based
ASRF	= Asymptotic Single Risk Factor
BCBS	= Basel Committee on Banking Supervision
BIS	= Bank for International Settlements
EAD	= Exposure At Default
EC	= Economic Capital
EL	= Expected Loss
ES	= Expected Shortfall
F-IRB	= Foundation Internal Ratings Based
LGD	= Loss Given Default
M	= Maturity
OECD	= Organisation for Economic Co-Operation and Development
PD	= Probability of Default
SA	= Standardized Approach
SME	= Small and Medium size Enterprises
VaR	= Value At Risk

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Risk measures + VaR

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