

**VRIJE UNIVERSITEIT AMSTERDAM**

# **Minimum Capital Requirement Basel II**

## **Credit Default Model & its Application**



**BMI Paper**

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## **Abstract**

The main objective of this paper is to review the first pillar, „capital requirement“, under the Basel II accord. In particular, our attention will be focused on the advanced Internal Ratings Based approach which allows banks to calculate required capital in relation to their credit risk represented by particular asset. Different credit risk modelling techniques such as PD, LGD, EAD and credit maturity are the main components embedded in Basel II capital requirement function. Under IRB approach firms are allowed to estimate their credit risk using own internal models.

The first part of this paper provides general information about Basel committee along with the Basel I and II accords. The second part is dedicated to the A-IRB approach, and in particular we focus on Capital requirement function and its structure. The basic fundamentals, where the Capital requirement function is based on, like ASRF and Merton model are discussed later. The end part of this paper provides some conclusive empirical research concerning some of the main components, embedded in regulatory function, such as assets correlations, maturity adjustment and LGD.

## Preface

This BMI paper is one of the last compulsory subjects of the study Business Mathematics and Informatics at the master level. The main objective of this paper is to do some relevant literature research combining two of the three study disciplines covered by study BMI. However, this paper will treat mainly the mathematical aspects arising on the economic field; the informatics has also been applied to support these two aspects.

Economy and its mathematical aspects have always attracted my attention. During my high school period in Nepal I used to participate in various discussion activities which were organized by school. This motivated me to choose a subject related to the banking financial system. I kindly thank my supervisor Dr. Harry Van Zanten for his valuable comments and suggestions.

Amsterdam, June 2007

Youbaraj Paudel

## List of acronyms

A-IRB	Advanced Internal ratings approach
ALM	Asset Liabilities Management
BIS	Bank of International Settlement
EAD	Exposure At default
EAD	Exposure at default
EC	Economic Capital
ECB	European Central bank
EL	Expected Loss
EMU	Economic and Monetary Union (mainly Europe)
ES	Expected Shortfall
FI	Financial institution
FIs	Financial Institutions
F-IRB	Foundation Internal ratings approach
IRB	Internal Rating Base
LF	Loss Function
LGD	Loss Given Default
SA	Standardised approach
SME	Small and Middle Enterprises
UL	Unexpected Loss
VaR	Value at Risk
QIS5	Quantitative Impact Study 5

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## 1 Introduction

The landscape of financial market has been changed very rapidly through last few decades. Various elements like; globalization, cross border/section merger and acquisition, growing strategic partnering among the companies, changes in regulatory environment and changes in micro/macro elements have created not only many opportunities but also many threats. All these changes have made the market much more complex and less transparent for financial institutions. The widening scope and scale, both in products and services, within the companies have forced the conglomerates to operate at the edge regulatory framework. These unprecedented changes are demanding more attention from the FIs in assessing their creditworthiness, not only on individual basis as before but also on risk modelling based on entire portfolio. To maintain and monitor the financial activities within the financial institutions there are various prudential organizations and authorities at national and international level. The main objective of such organization is to promote the awareness of matters that are relevant for safeguarding the financial stability in all levels in the financial institutions. So, the central banks determine the capital requirement that the banks are required to retain as buffer to overcome the unexpected losses. Through monitoring, supervision and creation of regulations the BIS tries to facilitate for a smooth and efficient reallocation of financial resources among the various partners. Due to these changes in financial institutions the usefulness of the credit risk management has been increased to unprecedented level.

In the first three chapters we will discuss the informative part of Basel accord and its responsibilities in the banking financial sector. The later three chapters are devoted to the minimum capital requirement and its components such as PDs, LGD, assets correlations and maturity adjustment. Since the capital requirement function is supposed to be portfolio invariant the capital function is based on so-called ASRF model purpose, which is briefly discussed. All components of capital requirement function are discussed in chapter 4. To provide an idea about how to model the credit risk in practice we have discussed the KMV credit risk modelling technique based on

Merton option pricing model, in chapter 5. Deriving some of the basic components like PDs and conditional PDs an adaptation version of Merton model is used. We give brief description and explained the idea behind the Merton model which is mostly used to forecasting default credit risk. The final part of the paper uses some empirical research to measure the impact of different components embedded in capital function.



## 2 Basel accord on banking supervision

Basel committee, originated from 1974, has played a great role in standardizing bank regulations across the jurisdictions. The committee consists of various representatives from central banks and regulatory authorities. The objectives of the committee have evolved over last many years. Among many other tasks the committee is charged for defining the roles of regulators in cross-jurisdictional situation; ensuring that international banks and financial institutions don't escape comprehensive supervision; and creating fair competitive financial market imposing uniform capital requirements [\[1\]](#).

Banks are different from normal companies as they trade on money which they actually don't possess, that makes them more sensitive for any risk arise in the market. They attract money from third parties, offer that money to other parties for some competitive risk premium and profit from the spread. Since the situation and position of debtors can change with the time it could be possible that they cannot payback the loans. This implies that the banks confront with the credit risk.

One of the main goals of the Basel committee has been to limit the credit risk such that the customers, i.e. depositors, are protected and which also helps to overcome the potential disturbance in the financial market. The Basel committee was also the designer of the Basel I and II accords where the main issues are the stability of financial markets and fair competition among the banks.

### 2.1 Basel I

The main goal of this accord was to set up a flexible regulatory system concerning the capital requirement. It was not much advanced as Basel II accord. The main rule embedded in Basel I was that the banks were required to hold a minimum reserve of 8% of risky assets [\[17\]](#).

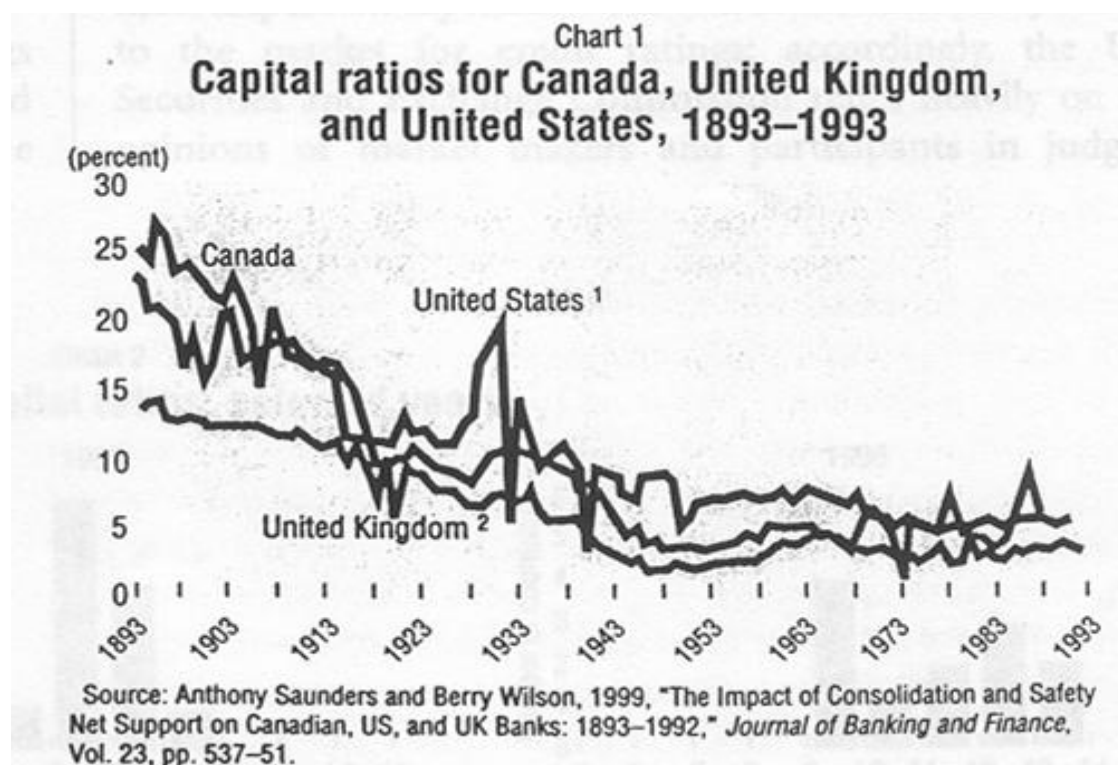


Figure 1.1: evolution of capital requirement

However, there were various exceptions on assessment of capital requirement depending on the kind of risks. For instance, the loans issued to the state-government were supposed to be the least risky which could be resulted in very low capital requirements or even 0% capital requirement. In the same manner the mortgages were treated as less risky loans compared to the other normal loans since in the case of counterpart's default the bank still could get its money, partially or fully, since the concern properties are collateral. Mortgages were so called 50% risk weighted loans where only about 4% of the invested capital was enough for reserve buffer to meet the capital requirement criteria. The main weaknesses of Basel I was that it dealt with credit risk in a simple manner and the market risk was afterthought while operational risk wasn't dealt with at all.

## 2.2 Basel II

Basel II is the second Basel accord and represents recommendation by bank supervisors and central bankers from the 13 countries making up the Basel committee

on Banking Supervision to revise the international standards measuring the adequacy of bank capital. This is the extended and modified version of Basel I accord from 1988 [2].

Basel I has been now seen as incapable and outdated version as the financial institutions and their operating filed had been changed through the past enormously. To adopt the new situation in the financial world the Basel I was broadly modified to Basel II. The main features of this accord are [1]:

- It is expected that the central banks of about all countries will incorporate this regulation in their national banking supervision regulation.
- It has the responsibility to monitor, supervise and to setup the financial regulations.
- It strives for customer protection, prudential supervision and conduct of businesses.
- Accord will enhance competitive equality.
- Constitute more comprehensive approach for addressing risk.
- Focus mainly on internationally active banks.

Basel II consists of the following three pillars which we will discuss in section 2.2.1.

- Capital requirements depending on the actual risk,
- Supervisory review process,
- Market discipline, more transparency in providing the information by the banks.

The main difference between Basel I and II is that the last one allows the banks to choose one method from standardised approach or internal rating based (IRB) approach. The first one is the extended version of Basel I with broad adjustments. In Basel I the standard rate of capital requirement was fixed at 8% percent irrespective of the ratings while the Basel II asses this amount taking the ratings in account. The second method, IRB approach,

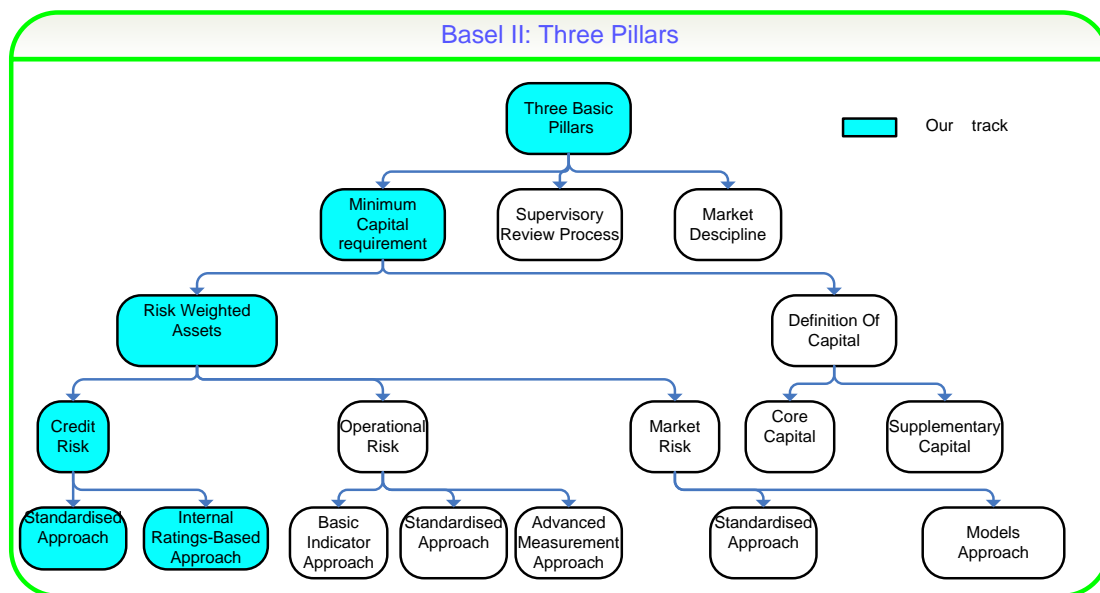
which relies heavily upon bank's internal assessment of its counterparties and exposures, gives the banks the opportunity to choose a suitable method for assessing the risks remaining within the supervision criterion imposed by the authorised supervision committee.

According to this method banks are supposed to provide all the information about the counterpart's defaulting risk, namely the chance that one of her counterpart will go

default, and the percentage of amount which is already assumed to be dubious and would be difficult to get back. The used method should be statistically significant and fulfil all the requirements imposed by the supervision committee. The core idea of this method is first to classify the customers in different groups (ratings<sup>1</sup>) depending on their risk profile and position, and secondly to make an assessment of necessary capital requirement depending on the earlier mentioned information. We will discuss this part in detail in coming section.

### 2.2.1 The three pillars

The Basel II framework describes a more comprehensive and precise measure and the minimum regulatory standards for capital adequacy<sup>2</sup>. The Basel II capital framework consists of so called three pillars: a) minimum capital requirement b) a supervisory review process c) market discipline. Figure 2.1, here below, reflects the picture of three pillars along with the extension part of minimum capital requirement which particularly deserve our attention in this paper. This paper discusses mainly the points depicted in blue background.



<sup>1</sup> Banks rate their counterparts depending on their default probabilities, solvency ratios, and future expectation. Though the objectives of rating remain same among the banks they can use different methods and ideas to assess it. There are various rating agencies like: S&P, Dun&Bradstreet, A.M. Best and Fitch ratings.

<sup>2</sup> This represents the amount of capital relative to the banks and FI's loans and other assets. As well the national banking regulatory authorities as the international banking regulatory organizations (i.e. BIS, ECB) require that the banks hold a certain minimum amount of equity capital against their risk-weighted assets to overcome the problems like liquidity and deposit SF.

Figure 2.1: Basel II three pillars

## I. First pillar: Minimum Capital Requirement

The main goal of this pillar is to provide improved risk sensitivity in the manner that capital requirements are calculated including three main risk components: credit risk, market risk and operational risk. It is possible to calculate these three risks using different approaches such as VaR and loss functions (LF). To calculate these components it is necessary to use advanced methodologies which make use of advanced data collection and sophisticated risk management techniques.

Basel II capital requirement requires banks to take all three kinds of risks into account while managing their credit risk. The overall regulatory requirement depends on the overall assessment of bank's different risks, mainly; market risk, credit risk and operational risk:

**Market risk:** market risk is caused by the day to day fluctuation in assets or securities prices which could be resulted in loss or profit. This risk is common to an entire class of assets and liabilities. Since this risk is caused by market itself it can't be diversified away. For instance changes in exchange rate, interest rate fall under this risk. Also a natural disaster<sup>3</sup> which can have great impact on the prices of assets and securities are known as market risk. Basel II has proposed two main approaches to calculate this risk: standardized approach and model approach.

**Credit risk:** this risk arises due to uncertainty in counterparty's (also called obligor's) ability to meet its commitments towards his borrower. Since there are various counterparts<sup>4</sup> and different types of obligations<sup>5</sup> credit risk takes different forms. For assessing the credit risks from a counterpart Probability of Default, credit exposure and recovery rates are required [19]. The different approaches for credit risk assessment are discussed in **chapter 3**.

**Operational risk (OR):** risk arising from the losses that are caused by the failed or inadequate processes, people or system or from external events. Basel II motivates

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<sup>3</sup> Actually, when defining in a precise way this risk falls under category operational risk!

<sup>4</sup> Examples of counterparts are individuals, banks, sovereign governments and various corporations.

<sup>5</sup> Derivative (forward, future, swaps, calls, put) transactions, auto loans, individual loans, loans to SME are the example of obligations.

banks and FIs to manage their operational risk not only at each business-level but also at holding level. The capital requirement for OR has been fixed at the level of average over the previous three years of a fixed percentage of positive annual gross income. There are three different approaches - Basic Indicator Approach (BIA), Standardized Approach and Advanced Management Approach - proposed by Basel II for assessment of OR capital requirement.

## **II. Second pillar: Supervisory review process**

Second pillar deals with the regulatory responses to minimum capital requirement (first pillar). Moreover, it provides a concrete framework to cover all other risks that a bank may face. Some of these risks are name risk, legal risk and liquidity risk which are known as residual risks in the accord.

The key principles of supervisory review are:

- The banks have appropriate process for assessing overall capital adequacy
- Supervisor and regulatory authorities may review capital assessment and, if necessary, take action
- Supervisors expect banks to operate above the minimum capital requirement
- Supervisors and regulatory authorities will intervene if FI's operate under the minimum requirement

Beside these actions supervisor's attention is also allocated to: transparency and accountability and interest rate risk in the banking book.

## **III. Third pillar: Market Discipline**

The third pillar deals with making information available for the customers and other mentioned organization by the banks to create disclosed market. This is designed to create a fair environment for competition among the banks in the market and to protect the customers. Moreover, the supervisory committee puts eyes on the scope of application, composition of capital, adequacy of capital, risk exposures and assessment.



### 3 Risk management and methodologies

The supervisory committee requires banks to provide minimum capital requirements for credit, market and operational risk. Therefore the committee has defined different approaches in the management and measurement of banking risks. There are three main approaches proposed by committee for credit risk assessment mentioned in the Basel II agreement, namely: Standardised (section 3.1), Foundations Internal ratings based (F-IRB) and Advanced Internal Ratings Based (A-IRB) (section 3.2) approaches. Though the end objective of all approaches is to calculate the capital requirement, they differ considerably on level of difficulty. We will discuss all these three approaches briefly in coming paragraph.

It should be clear that the minimum capital requirement imposed by authorities wouldn't always be enough to cover various financial risks faced by banks since they are mainly meant to cover public losses due to bank's failure. Therefore we can find different types of reserves used by banks to tackle the potential losses.

**Regulatory Minimum Capital Requirement (RC):** Briefly, the minimum capital requirement is the amount held by banks for business taking into account the public costs of bank failure. This amount will be set up by the regulatory authorities and supervisors [4]. The regulatory capital<sup>6</sup> under Basel I was calculated with the following simple formula:

$$\frac{\text{Total capital (unchanged)}}{\text{Credit risk+Market risk+Operational risk}} \geq \text{The bank's capital ratio (minimum 8\%)} \quad (3.1)$$

However, the capital requirement under Basel II is more complicated since it treats different type of assets in a distinctive way depending on their risk profiles and type.

<sup>6</sup> Regulatory capital consists of two components, so called tier 1 and tier 2 capitals. Tier 1 capital (core capital) consists largely of shareholder's equity. This is amount paid up to originally purchase the stock plus retained profit and subtracting accumulated assets. i.e. if original price €100 per stock and the banks makes €10 profit since purchasing point(no losses at all) then the tier 1 capital after 2 years is €120.

Tier 2 (supplementary) capital consists of several classification of this tier. For instance, they are classified as undisclosed reserves, revaluation reserves, general provision and hybrid instruments.



We will discuss capital requirement under Basel II accord in more detail in paragraph 3.2.

**Economic Capital (EC):** the amount of capital that a firm or bank determines to be prudent, desirable and achievable of the long term in absence of regulatory requirements (see figure 4). The main difference between the RC and the EC is that the EC is introduced by bank itself in the absence of capital regulation while the RC is minimum capital required by Basel II. Banks use credit portfolio method (i.e. Merton model) to determine this amount. EC can be defined in two levels: i) at portfolio and ii) transaction level [22].

*Portfolio level:* amount of capital needed in order to make sure that the bank will stay solvent with some given probability (i.e. 99.9%). The required EC as VaR (a threshold) at level  $\alpha$  (i.e. 99.9%) is defined as following.

Say, our portfolio-wide loss is given by:

<p>Say, portfolio-wide loss is given by <math>L = \sum_{i=1}^n L_i</math></p> <p>Where <math>i = \text{obligor } 1 \dots \text{obligor } n</math>, and <math>L_i</math> is loss per counterpart</p> <p>Then, EC at portfolio level (UEL+EL): <math>EC = \text{VaR}_\alpha(L)</math></p>	(3.2)
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*At individual transaction level:* the fraction of total capital to attribute to each transaction (sub-portfolio) to cover the risk, this is expressed as follow:

$$EC_i = E[L_i | L = \text{VaR}_\alpha(L)] \quad (3.3)$$

**Capital at Risk (CaR):** this is risk based capital, which will be required to cover all expected losses and is also known as risk-based capital. In other word, banks hold this amount of capital based on the assessment of risk to protect customers against adverse developments in its financial position.

In coming section we discuss the three main credit risk management approaches proposed by Basel II supervisory committee.

### 3.1 Standardised approach (SA)

This approach is the minimum requirement imposed by the Basel committee on the banks and other financial institutions (FIs). Because of its simplicity a large number of banks are adopting this method to evaluate their credit risk. A research conducted by the KPMG (2004) shows that around 35% of institutions were planning to opt this simple method [15].

The SA increases the risk sensitivity of the capital framework by recognizing that the different counterparts within the same categories can present far different risk to the financial institutions. This means; instead of placing all the commercial loans in one specific weight bucket, i.e. in 100% bucket, the SA takes into account the credit risk profile of the borrower. All the derivatives and assets from various classes are assigned weights depending on the risk profile of concerned instruments<sup>7</sup>. These weights are provided by the known credit ratings<sup>8</sup> agencies like S&P 500, Fitch, Moody's, Dun&Bradstreet and A.M. Best [16].

The minimum capital requirements based on this method is given by following formula:

$$\sum_{i=1}^n RW_i \times A_i = RWA \quad (3.1.1)$$

$$RWA * 0.08 = RC \quad (3.1.2)$$

Where,

$RW_i$  = risk weight to asset  $I$ ;

$RWA$  = risk-weighted assets,  $A_i$  = Assets  $i$ , ( $i = 1, \dots, n$ );

$RC$  = Regulatory capital

As shown in formula 3.1.2, the minimum capital requirement that banks have to hold is the 8% of its risk weighted<sup>9</sup> assets.

Figure 3.1 reflects the risk weights for various categories of credits which are acquired depending on the credit ratings.

<sup>7</sup> All kinds of derivatives and assets are also known as financial instruments.

<sup>8</sup> Lender's estimate of an individual's, corporation's and FI's creditworthiness based on the past history of borrowing and paying, employment profile and the information supplied by the prospective borrower in a credit application, as well as the applicant's credit report.

<sup>9</sup> Risk weight functions map bank-reported risk parameters to exposure risk weights.

As the sovereign credits<sup>10</sup> are classified in different categories, depending on the potential risks they can carry with them, the risks weights differ considerably. Claims on sovereigns considered to be of very high quality are eligible for 0% risk weights. In the unrated retail category the mortgages are rated at 35% while other retail is fixed at 75%. This could be due to the fact the mortgages are collateral and the other retail not. As it can be seen the unrated credits are set into 100% risk weights.

Claim	Assessment						
		AAA - AA-	A+ - A-	BBB+ - BBB-	BB+ - B-	Below B-	Unrated
<b>Sovereigns (Export credit agencies)</b>		0% (1)	20% (2)	50% (3)	100% (4-6)	150% (7)	100%
<b>Banks</b>	<b>Option 1<sup>1</sup></b>	20%	50%	100%	100%	150%	100%
	<b>Option 2<sup>2</sup></b>	20% (20%) <sup>3</sup>	50% (20%) <sup>3</sup>	50% (20%) <sup>3</sup>	100% (50%) <sup>3</sup>	150% (150%) <sup>3</sup>	50% (20%) <sup>3</sup>
<b>Corporates</b>		20%	50%	100%	BB+ - BB- 100%	Below BB- 150%	100%
<b>Retail</b>	<b>Mortgages</b>						35%
	<b>Other retail</b>						75%

Table 3.1: Risk Weights<sup>11</sup> depending on the assets characteristics<sup>12</sup> (source: [BIS](#))

<sup>10</sup> The sovereign credit is the credit of a sovereign country backed by its state financial resources. Since some of the countries are in financial trouble which can create high potential risk for concerned credit they are rated very low and have high risk weights.

<sup>11</sup> Risk weights are determined based on the type of assets or provisions. Once risk weights for different buckets of assets are fixed we can calculate the risk weighted assets (RWA). 8% of this RWA is the 'required capital'

<sup>12</sup> Under the first option, all incorporated banks in a certain country will be assigned a risk weight one category less favourable than that assigned to claims on sovereign country. Under the second option, the risk weights are dependent of the external rating of banks itself and differ with the maturity of claims.

## Example 3.1 standardized approach

Suppose bank EVEREST has the following credit portfolio:

Claims	Amount (in million)	Risk weight
Amsterdam municipality	€30	0%
Corporate 1( A+ - A- rated)	€15	50%
Mortgage	€30	35%
Other retails	€40	75%

Using formula 3.1.1 & 3.1.2 we can now assess the amount the bank has to hold according to SA approach.

$$\sum_{i=1}^n RW_i \times A_i = RWA, \text{ where } A_i \text{ is the asset } i, i= 1,2,3,4$$

Thus the risk weighted asset is:

$$RWA = 0 \times 30 + 0.5 \times 15 + 0.35 \times 30 + 0.75 \times 40$$

$$= \text{€}48 \text{ million}$$

Using formula 3.1.2

$$RWA \times 0.08 = RC$$

$$= 0.08 \times 48$$

$$= \text{€}3.84 \text{ million}$$

Thus the amount that the EVEREST bank has to hold to fulfil the regulatory capital is €3.84 million.

### 3.2 Internal Ratings-based (IRB) Approach

The IRB approach under the Basel II provides a single framework by which the important set of risk components are translated into minimum regulatory capital requirement. Under this approach banks are allowed to use their own internal estimates to assess the credit-worthiness of borrowers to calculate the credit risk in their portfolio. Banks that receives supervisory approval to use the IRB approach to estimate their credit risk may relay on their own internal estimates of risk components in determining capital requirement. The risk components included in the RC function are among others PDs, EAD, LGD<sup>13</sup> and effective maturity. These components are generally used to measure credit risk. Briefly, the IRB approach is based on the measures of EL and UEL. Different risk exposures serve as input for the risk weight function that has been developed for distinctive asset classes such as; corporate, retail, sovereign etc.

All in all, the core idea of this approach is to translate the individual risk components from various types of credits into potential estimation of losses (i.e. EL, UEL). Moreover, this approach uses the collected information and processed in the banks' own counterparty evaluation. The risk weights for the IRB approach, i.e. the factor calculated for each risk category and by which the sum of all loans in a specific risk class is to be multiplied to obtain the **risk-weighted capital** base, is calculated by bank itself.

The IRB approach is to be found in two forms:

**Foundation IRB approaches:** under this method, banks estimate the PDs or LGD themselves, and other inputs needed for calculation of capital requirement are provided by specific bank supervisors. Banks which are allowed to use this method are supposed to meet the requirements mentioned in Basel II.

**Advanced IRB approach:** banks which meet the requirements for overall ratings system and process as well as the other incremental requirements, which are related to the estimation of all risk parameters like PD, LGD and EAD, are permitted to use their own estimation of inputs to the risk weight function [\[10\]](#).

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<sup>13</sup> PDs, LGD and EAD are the main inputs for IRB approach.

Figure 3.2.1 summarizes the advantages of different methodologies in relation with their level of complexity.

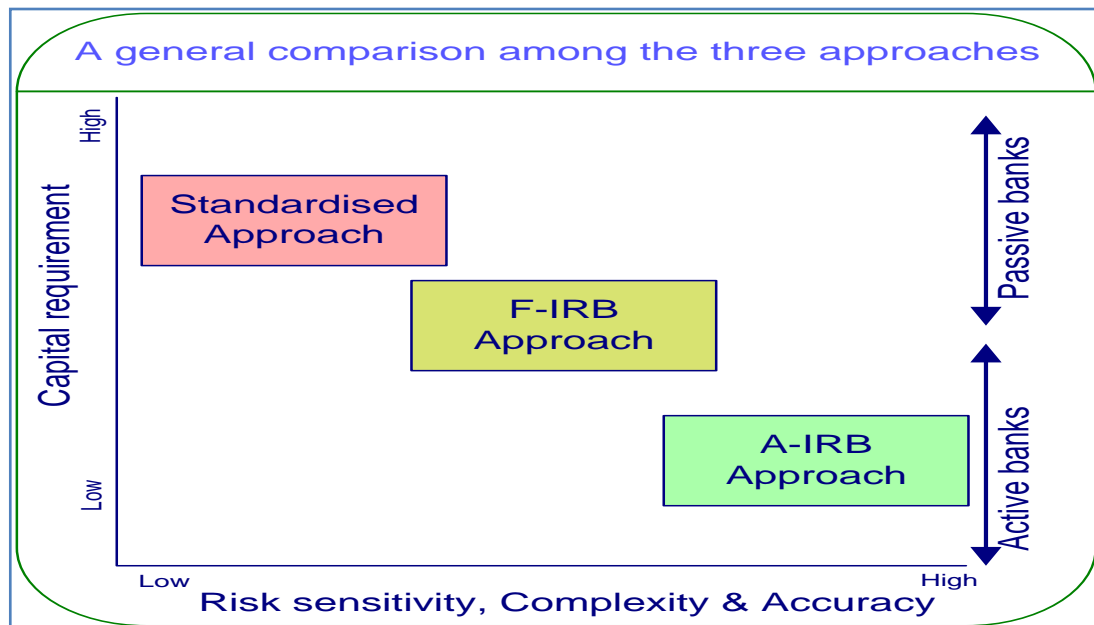


Figure 3.2.1: a comparison among three approaches

Banks willing and allowed to use IRB risk management approach are supposed to pay attention to the following points.

- Analyses of risk components: the risk parameters should be estimated as introduced by banks. Nevertheless, some of the parameters are estimated by supervisors depending on the type of model used for RC assessment.
- Banks should establish the risk-weight function: risk-weight functions transform the risk components to the risk-weighted assets (equation 3.1.1) and therefore capital requirement.

Banks are supposed to meet the minimum standard requirements in order to use the IRB approach for specific asset classes.

### 4 Credit risk modelling under IRB approach

In section 3, we introduced briefly the term **Regulatory Minimum Capital Requirement (MCR)**. In this section we discuss the **MCR** model specification and its application under Basel II.

The MCR is defined as the standardized amount in place for banks and other depository FIs that relates how much liquidity is required to be held for a certain level of assets through regulatory authorities like **BIS**. These requirements are put into place to ensure that these FIs are not participating in investments that increase the risk of default and that they have enough capital to sustain operational losses while still meeting the daily customer's requirements.

Minimum Capital Requirement function proposed by Basel II consists of various components. Based on the supervisory approval companies are assumed to estimate various components embedded in proposed RC model. So, companies with supervisory approval for Advance IRB approach have freedom to estimate the following RC's components internally:

- Probability of Default (PD)
- Loss Given Default (LGD)
- Maturity (M)
- Exposure at default (EAD)

Figure 4, here below, represents the familiar **regulatory capital Function** to credit risk under IRB approach.

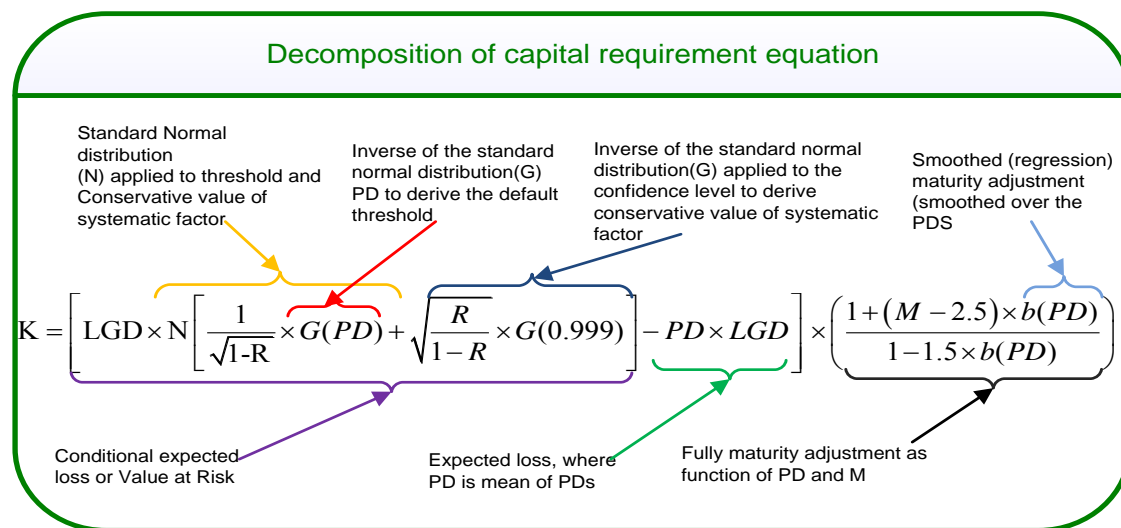


Figure 4: Decomposition of capital requirement function into various risk components

Where,

<sup>14</sup>Maturity adjustment  $b = (0.11852 - 0.05478 * \ln(PD))^2$  and,

$$^{15}\text{Effective Maturity}(M) = \frac{\sum_{t=0}^T t * CF_t}{CF_t},$$

Where  $CF_t$  denotes the cash flows contractually payable by the borrower in period  $t$

And,

K = Capital Requirement

LGD = Loss given default

EXP = Exponential

PD = Probability of Default

EAD = Exposure at Default

$N(x)$  = The cumulative normal distributions function for standard random variables.

$G(x)$  = The inverse cumulative distributions function for a standard normal random variable<sup>16</sup>.

$b(PD)$  = Smoothed regression maturity function

Though at first glance it seems that the **RC** function is quite arbitrary and technical, many economic concepts embedded in it make it meaningful. As we can see the **capital requirement** function consists of various components like: LGD, PD, maturity adjustment etc. In coming sections we will discuss the **RC** model and its components separately.

#### 4.1 RC model specification

Capital charges are designed to satisfy a portfolio-level insolvency target (VaR rule, see figure 4.1). For the calculation of the **regulatory requirement** under the IRB approach this **credit risk model** is assumed to be portfolio invariant. This means that the required capital for any loan should only be dependent on the risk of that loan and should not depend on the portfolio added to it.

<sup>14</sup> Since the maturities of different loans in various categories (ratings) are sensitive to the level of risk, this formula adjusts that level by processing time and assigning a certain factor to the maturity.

<sup>15</sup> Weighted average of portfolio's maturities is called effective maturity.

<sup>16</sup> To calculate the  $N(x)$  (cumulative standard normal distribution function) we can use NORMDIST in EXCEL and for  $G(Z)$  (inverse standard normal distribution) NORMSINV.



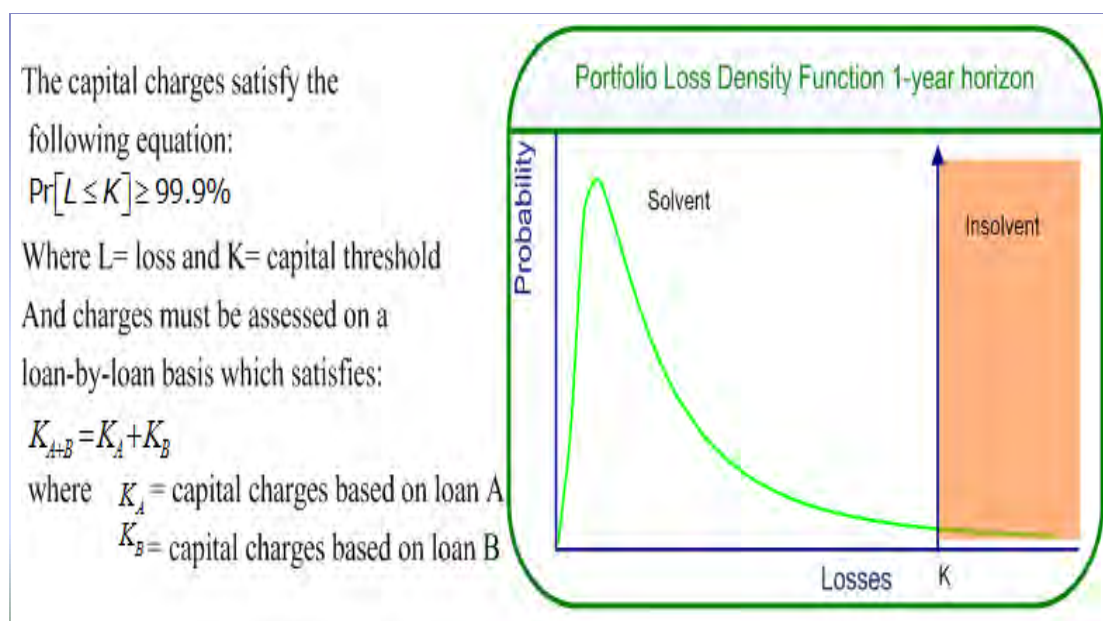


Figure 4.1: Basel II credit capital rule, portfolio-level solvency target

This IRB approach for credit risk modelling is assumed to meet this condition in order to be applicable within a wide range of FIs. However, this assumption makes recognition of institution-specific diversification difficult because diversification effects would depend on how well a new loan fits into an existing portfolio. To avoid this problem the Basel committee provides a Calibration facility within the IRB approach for well diversified portfolios.

#### 4.1.1 Asymptotic single factor model (ASRF)

The above mentioned portfolio invariant property in the capital framework has a large impact on the structure of the portfolio model. Gordy (2003) has shown only the models based on the so called **ASRF** principle can represent portfolio invariant methods. ASRF models are derived from an „ordinary“ credit portfolio based on the law of large numbers [11]. The idea behind the ASRF model is that when a portfolio consists of a large number of relatively small exposures, idiosyncratic risk associated to each individual exposure tends to cancel out one-another. Then only the systematic risk, which affects all obligors to a certain degree, has effect on portfolio losses [18]. In other words the ASRF model assumes that the given portfolio is well diversified so that one can easily calculate the required capital by focusing only on systematic risk. Calculating the **conditional expected loss (CEL)** for an exposure given an appropriately conservative value of the single systematic risk factor one can estimate

the sum of the **expected** and **unexpected** loss. The CEL for a specific loss exposure is expressed as a product of the probability of default (PD) and LGD [3].

The ASRF model is based on three main assumptions. Below we provide the mathematical concept behind the ASRF model and its assumptions.

**The first assumption states:** cross-exposures correlations in losses are driven by a single systematic factor  $X$ . This implies that the loss of each obligor is defined by that one factor. In mathematical form we have:

$$\Pr[L_A < I_A \cap L_B < I_B | X] = \Pr[L_A < I_A | X] \cdot \Pr[L_B < I_B | X] \quad (4.1.1)$$

Where,  $L_A$  = loss of obligor A,  $L_B$  = loss of obligor B,  $I_A$  and  $I_B$  are the capital exposure threshold for obligor A and B, and  $X$  represents for single systematic risk factor. The portfolio is infinitely-fine-grained, thus the idiosyncratic risk is completely diversified away.

**The second assumption states:** the portfolios are *infinitely-fine-grained*. This makes it possible that the individual losses of each obligor are conditioned only on systematic risk as the idiosyncratic risk is completely diversified away. Then the losses are completely defined by only one risk factor, namely the systematic factor. Then the expected loss for each obligor conditioned on that factor is given by:  $E[L | X]$ . Assume there is another function  $C$  of same systematic factor  $X$ , which has the same distribution function as the expected loss. Then, we get:

$$L | X = E[L | X] \equiv C(X) \quad (4.1.2)$$

Here, the loss conditioned on single systematic risk factor is precisely equal to the function  $C(X)$ , which means that the losses of each obligor are completely defined by  $X$ <sup>17</sup>.

**The third assumption states:** for most exposures loss rates are increasing in the systematic risk factor. Using the comonotonicity<sup>18</sup> rule we can write:

<sup>17</sup> In practical world the losses of obligors may always be correlated. Only, when a portfolio consists of infinitely many sub-components one can make this assumptions.

$$\text{If, } X_1 > X_0 \Rightarrow C(X_1) > C(X_0) \quad (4.1.6)$$

Using all these assumptions we can define the *ASRF capital rule*:

The  $\alpha^{\text{th}}$  percentile (the portfolio solvency probability target) of systematic factor  $X$ <sup>19</sup> can be defined as:

$$x_\alpha \equiv \inf \{x \mid \Pr[X \leq x] \geq \alpha\} \quad (4.1.2)$$

Now we set capital ( $K$ ) equal to the  $\alpha^{\text{th}}$  percentile (i.e. 0.999) of loss ( $L$ ) such that it ensures a portfolio solvency probability of  $\alpha$ . So we get the required capital:

$$\begin{aligned} K &= \inf \{k \mid \Pr[L \leq k] \geq \alpha\} \\ &= \inf \{k \mid \Pr[E[L \mid X] \leq k] \geq \alpha\} \end{aligned} \quad (4.1.3)$$

Now, using the previous information we replace the expected loss with function  $C(X)$  and get:

$$K = \inf \{k = c(x) \mid \Pr[X \leq x] \geq \alpha\} \quad (4.1.4)$$

Plugging in our  $\alpha^{\text{th}}$  percentiles of  $X$  in (4.1.4) then we get:

$$K = \inf \{k = c(x) \mid \Pr[X \leq x] \geq \alpha\} = C(X_\alpha) \quad (4.1.5)$$

The total loss of a portfolio is the sum of each individual loan (sub-portfolios). Assume sub-portfolios  $Y$  and  $Z$ , such that  $L = L_Y + L_Z$ , then the required capital for this portfolio is:

$$K = c(x_\alpha) = E[L_Y + L_Z \mid x_\alpha].$$

Since they are independent we can write:

$$\begin{aligned} K &= E[L_Y \mid x_\alpha] + E[L_Z \mid x_\alpha] \\ &= c_Y(x_\alpha) + c_Z(x_\alpha) = K_Y + K_Z \end{aligned}$$

<sup>18</sup> A random vector  $(X_1, \dots, X_n)$  is co-monotonic if there exists a random variable  $Y$  and non-decreasing functions  $f_i, i = 1, \dots, n$  such that  $(X_1, \dots, X_n) = (f_1(T), \dots, f_n(T))$  in distribution.

<sup>19</sup> The systematic risk (system-wide risk) factor, that effects all borrowers to a certain degree, in ASRF it is assumed to be same, are modelled with only one ("the single") systematic risk factor.

### 4.1.2 Average and conditional PDs

Probability of default represents the probability that the issued loans will not be repaid. This happens when the counterparty comes in financial crises or goes bankrupt. To calculate the PDs the historical data, risk profile & nature of investment and financing of counterparty are necessary. Mostly, these measurements are performed by known ratings agencies like S&P, A.M Best, Egan-Jones Rating . Under the IRB approach banks are allowed to provide these measures on their own.

<b>Standard and Poors' Cumulative Default Rates (Percent)</b>										
Rating	Year									
	1	2	3	4	5	6	7	8	9	10
AAA	0.00	0.00	0.05	0.11	0.17	0.31	0.47	0.76	0.87	1.00
AA	0.00	0.02	0.07	0.15	0.27	0.43	0.62	0.77	0.85	0.96
A	0.04	0.12	0.21	0.36	0.56	0.76	1.01	1.34	1.69	2.06
BBB	0.24	0.54	0.85	1.52	2.19	2.91	3.52	4.09	4.55	5.03
BB	1.01	3.40	6.32	9.38	12.38	15.72	17.77	20.03	22.05	23.69
B	5.45	12.36	19.03	24.28	28.38	31.66	34.73	37.58	40.02	42.24
CCC	23.69	33.52	41.13	47.43	54.25	56.37	57.94	58.40	59.52	60.91

Source : Standard & Poors' Report 2005

Table 4.1.2: Cumulative transition matrix representing the probability of default over time depending on the ratings (*see [Appendix A](#) for more explanation*)

In the previous section we described the ASRF model which forms the fundament for the Basel II **regulatory capital function** (figure 4). The implementation of ASRF model makes use of the so called average PD that reflects the default rates under normal business condition. These PDs are calculated by banks, and these are used to assess **conditional expected losses** (based on single systematic risk factor) using a **supervisory mapping function** (i.e. Merton model). The mapping function used to derive **conditional PDs** from average PDs is based on an adaptation of Merton's single asset model to credit portfolio. We will discuss the Merton model broadly in section 5.

### 4.1.3 Expected loss

Though it is very difficult to estimate the potential losses in advance banks are required to provide speculative expected losses. Therefore banks forecast the average

level of credit losses, called expected losses (EL), they expect to experience. EL is the mean of the loss distribution function depicted in figure 4.1.2.

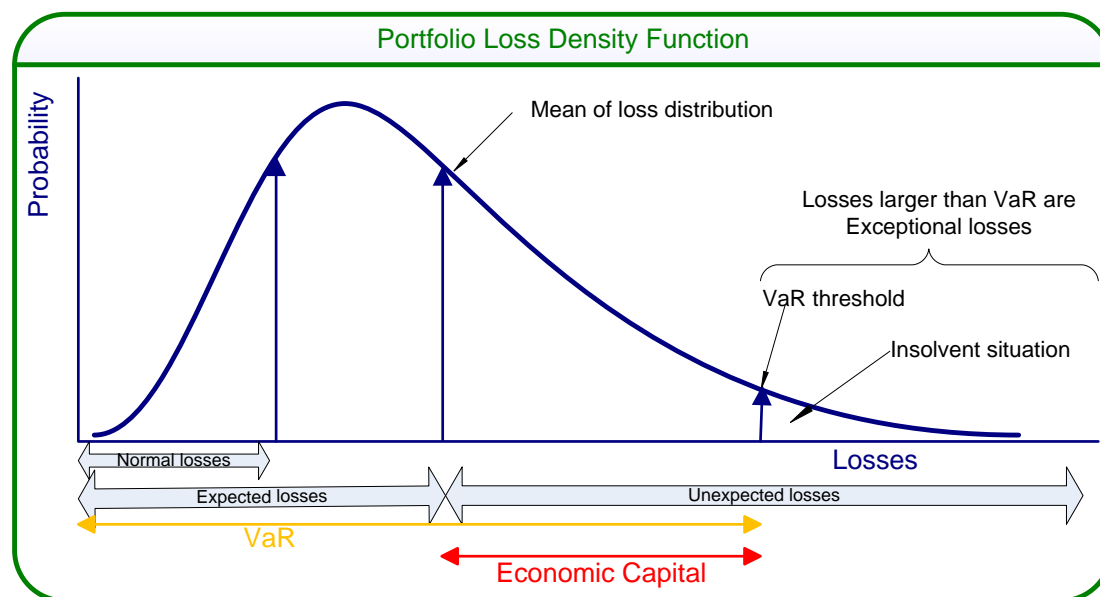


Figure 4.1.2: Portfolio Loss Density function (Merton model)

To calculate the EL we can use the equation (4.1.7):

$$EL = PD\% * EAD\text{€} * LGD\% \quad (4.1.7)$$

The term EAD is explained further in this section. The first part of the graph in figure 4.1.2 reflects the normal losses plus the losses which are to be forecasted by a bank. Financial institutions see this part as a cost component of doing business and try to manage it by a number of means, including through the pricing of credit risk exposure and hedging methods.

#### 4.1.4 Unexpected loss

The second parts of losses are unexpected losses<sup>20</sup> which do not occur each year, but if they occur they can be potentially very large. Since it is uncertain when these losses occur and what their grade of severity is, the bank hold economic capital to overcome any difficulties. The last part of unexpected losses, depicted in figure 4.1.2 (insolvent scenario), are much more severe and larger than the first and second one. In this scenario the bank makes such large losses that it effectively must default itself.

<sup>20</sup> Unexpected loss can also be defined as the spread of expected loss.

### 4.1.5 Loss Given Default (LGD)

The LGD [19] represents the percentage of exposures that the bank might lose in the case of an obligor's default. LGD consists of three components: principle losses, cost of carry and administrative cost [23]. Theoretically LGD can be calculated in various manners but the most familiar one is „gross“ LGD.

$$\text{Gross LGD} = \frac{\text{Total losses}}{\text{EAD}} \quad (4.1.8)$$

The second popular LGD is known as „Blanco LGD“, which is calculated through dividing the losses by unsecured portions of credit line<sup>21</sup>. When the collateral value is zero then „Blanco“ LGD is equivalent to „Gross“ LGD (see [Appendix E, figure E2](#)).

However, though **LGD** plays a great role in the **capital requirement** function Basel II does not provide an explicit function that transforms average LGDs into conditional LGDs (dependent on the systematic factor). Instead, under the A-IRB approach banks are requested to provide average LGDs, and LGDs that reflect the economic downturn conditions in situations where the loss severities are expected to be higher. The downturn LGD appears in the Basel II **capital function** in two forms: **conditional expected loss (CEL)** (which is the product of **conditional PD** and **downturn LGD** associated with an exposure) and **EL** (which is the product of average PD and downturn LGD).

LGD and downturn LGD in capital function

$$K = \left[ \text{LGD} \times N \left[ \frac{1}{\sqrt{1-R}} \times G(PD) + \sqrt{\frac{R}{1-R}} \times G(0.999) \right] - PD \times LGD \right] \times \left( \frac{1 + (M - 2.5) \times b(PD)}{1 - 1.5 \times b(PD)} \right) \quad (4.1.9)$$

LGD as part of ASRF model
LGD as part of Expected Loss

### 4.1.6 Exposures at Default (EAD) and Risk-Weighted Asset

Exposure At default (EAD) is a measure of forecasted exposure as calculated by the Basel Credit Risk Model for a period of one year. The Exposure at Default reflects the amount that a bank could lose in the case that loans suffer from lower valuation or

<sup>21</sup>Credit line represents the maximum amount of loan that can be extended to a customer, which is also known as line of credit.

even default. In a bank's internal system the bank is required to provide estimation of exposure of each transaction. While EAD is estimated through the use of standard supervisory rules under the F-IRB approach, under the A-IRB approach the banks themselves estimate the right EAD for each individual exposure depending on robust data and analyses which in its turn need to be validated internally and by the supervisors.

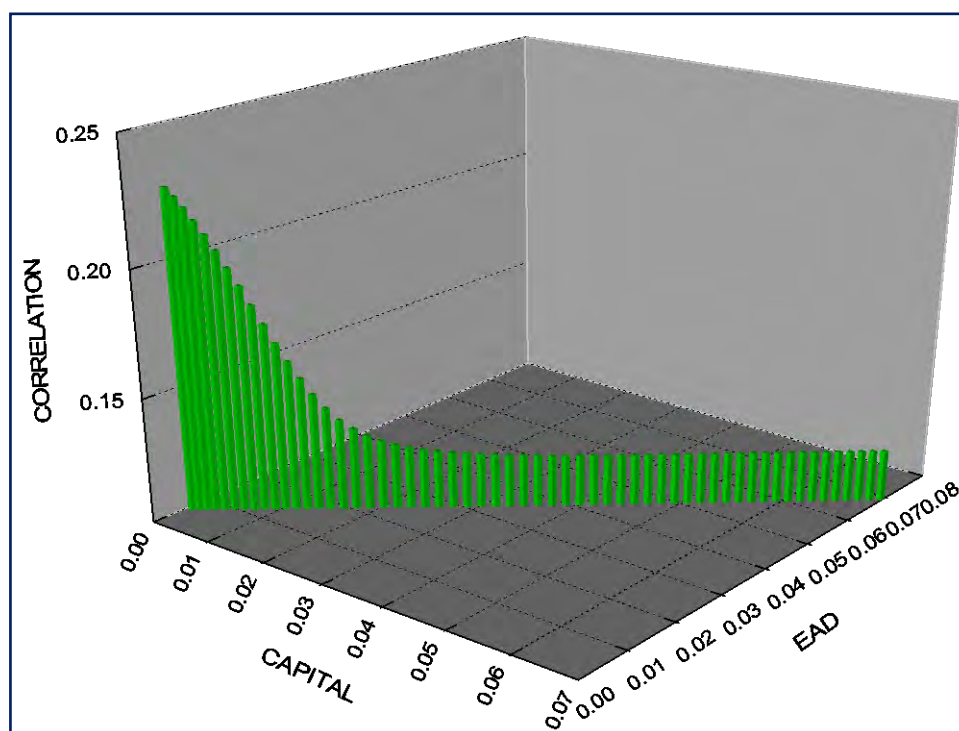


Figure 4.1.6: Exposure at Default vs. Required Capital & Correlation

The minimum capital requirement ( $K$ ) is based on the percentage of assets weighted by risk (risk exposure). Basel II imposes an 8% minimum capital requirement threshold for FIs which is the lowest percentage of risk-weighted assets. The purpose of risk-weighted assets is to move away from the static capital requirement. Instead, it is based on the degree of risk of a bank's assets. For instance, loans that are secured by a letter of credit will be weighted riskier than a collaterally secured mortgage loans. The amount of risk-weighted assets for a bank is expressed as follow (*see Appendix E, figure E2*):

$${}^{22} \text{Risk-weighted assets (RWA)} = K * 12.5 * EAD$$

Where,

<sup>22</sup> In terms of minimum amount of capital that is required within banks and other FIs, depending on the % of assets, weighted by risk.

$K$  = required amount of capital, 12.5 is the adjusted minimum capital ratio (which is normally 8% → read as 8.0).

## 4.2 Calibration of RC model

Some assets are less sensitive to losses than others as they differ in the types and features. As we noticed already mortgages are assumed to be less risky compared to retails or small enterprise assets since mortgages are collaterals. In the same manner the credits with longer maturity are assumed to be riskier than the credits with short maturity. So, while calculating Required Capital supervisory committee provides the flexibility of RC model calibration which allows correlation and maturity factor adjustment for distinctive assets. Notice, some of the components of RC model are provided by supervisory authority to meet this requirement. One of them is, the borrowers' correlations that reflect the dependencies of obligors on the overall economy with a single risk factor and the second, confidence level which is fixed at 99.9% level (i.e. a bank is expected to suffer losses which exceed the level if capital requirement on average in thousand years). This confidence level seems to be quite high, but this level is chosen to protect from estimation errors which could arise from banks internal assessment of PDs, LGD and EAD. There is also maturity adjustment possibility for different assets categories. The different adjustments concerning the assets correlations and maturity for specific assets are discussed here below.

### 4.2.1 Assets correlations

As we previously pointed out the ASRF model is based on a single systematic risk factor which may be interpreted as the state of the global economy. The assets correlation express the degree in which the asset value of one obligor depends (correlates) on the asset value of another obligor. In the same manner, assets correlations could also be described as dependencies of the obligor's assets on the entire state of the economy –all obligors are connected with each other with this single factor.

The different loans in different assets categories are characterized by distinctive risk features. These risk features can have considerable effect on the amount and kind of credit risk banks are exposed to. Therefore, the Basel committee has provided the



possibility to adjust the assets correlation for different business segments within the common **minimum capital requirement** function. Below we provide these alternatives applicable for corporates, sovereigns and banks. As already stated, the common capital requirement can be expressed as:

Assets correlation in Capital Function

$$K = \left[ \text{LGD} \times N \left[ \frac{1}{\sqrt{1-R}} \times G(PD) + \sqrt{\frac{R}{1-R}} \times G(0.999) \right] - \underbrace{PD \times \text{LGD}} \right] \quad (4.2)$$

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

Assets correlation to be determined by asset class

The correlation function for bank and sovereign exposures is given by:

$$\text{Correlation}(R) = \frac{0.12 * (1 - \text{EXP}(-50 * PD))}{(1 - \text{EXP}(-50))} + 0.24 * \frac{[1 - (1 - \text{EXP}(-50 * PD))]}{(1 - \text{EXP}(-50))} \quad (4.2.1)$$

For corporate borrowers, the correlations are computed by equation (4.2.1) and then modified as follow:

$$\begin{aligned} & \rho_i - 0.04, \text{ if } S_i \leq \text{€}5 \text{ million} \\ & \rho_i - 0.04 * (1 - (S_i - 5) / 45), \text{ if } \text{€}5 \text{ million} \leq S_i \leq \text{€}50 \text{ million} \\ & \rho_i, \text{ if } S_i > \text{€}50 \text{ million} \end{aligned} \quad (4.2.2)$$

Where, the  $S_i$  is annual sales for firm  $i$  and  $\rho_i$  represents the correlation of firm  $i$ . Hence, the assets correlations for small institutions are lowered.

There are many other exceptions and therefore individual adjustments are necessary. In the same manner the correlations for Retails, Equities and others can be found using the equation (4.2).

$$\text{Correlation}(R) = \frac{0.12 * (1 - \text{EXP}(-35 * PD))}{(1 - \text{EXP}(-35))} + 0.24 * \frac{[1 - (1 - \text{EXP}(-35 * PD))]}{(1 - \text{EXP}(-35))} \quad (4.2.3)$$

Nonetheless, the assets correlations framework was developed depending on the time series analysis by supervisors from the G10 countries. The general conclusion can be summarized as follow:

- Generally, the correlations decrease with increasing PDs. This is consistent with the fact that higher PDs mean high individual risk and thus, mostly, low correlation with other obligor's credit components.

- Asset correlation increase with the size of a firm. This could be explained the fact that the bigger the institutions the more dependencies (many components, i.e. loans) on the overall market economy.

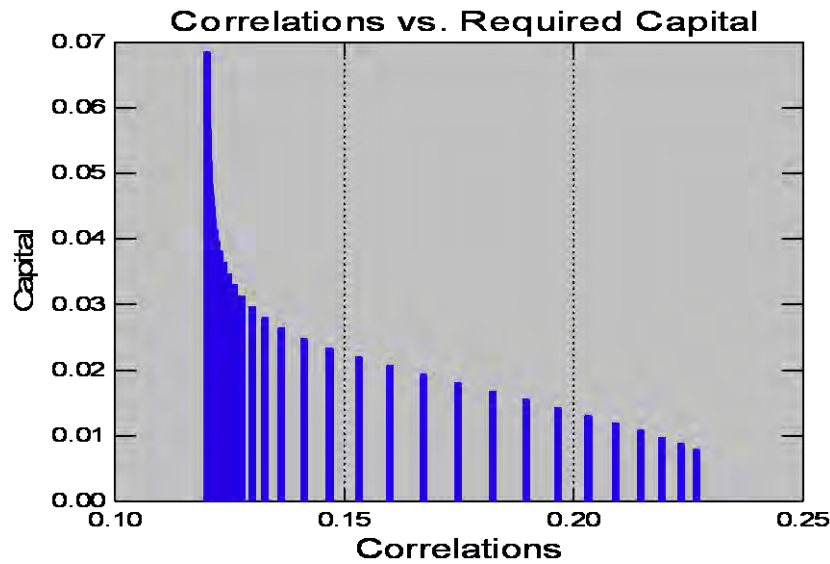


Figure 4.2.1: Required Capital vs. Assets Correlations<sup>23</sup>

While working with the capital requirement function the correlations interval is limited between 24% (lowest PDs: i.e. 0), and 12% (highest PDs: i.e. 100%). Correlations falling in this interval are modelled by an exponential function that reflects the dependencies on PDs. The so called „K“ factor is used to adjust the pace of this exponential component. To adjust this correlation function to the firm-size we should include the related term from equation (4.2.2) in equation (4.2.3).

**Decomposition of correlation function used in RC**

Correlation for highest PD (100%)

Correlation for lowest PD (0%)

Factor weights between high and low PDs (exp weights)

K factor

$$\text{Correlation}(R) = \frac{0.12 * (1 - \text{EXP}(-50 * PD))}{(1 - \text{EXP}(-50))} + 0.24 * \frac{[1 - (1 - \text{EXP}(-50 * PD))]}{(1 - \text{EXP}(-50))} \quad (4.2.4)$$

<sup>23</sup> Graph generated using the SYSTAT software

### 4.2.2 Maturity adjustment

Generally a portfolio consists of various assets with different maturities. It is already a common thinking in the financial world that the credits with long maturity are considered riskier than those with short maturity (*see Appendix E*). As a consequence the capital requirement also should differ depending on the credit maturity. Hence, the required regulatory capitals for long-term credit are generally higher than for short-term credit.

The maturity adjustment included in regulatory function is based on so called „make-to-market“ credit risk model. This implies that the loans with high PDs have lower market value today compared to the loans with lower PDs with the same face value. This is because the investors take into account the expected loss plus different risk-adjusted discount factors. Maturity effects are larger for low PDs loans than for higher PDs loans because there is higher possibility of downgrading for low PDs loans. The capital function takes this fact into account and applies a relatively higher maturity adjustment factor for low PDs and a lower factor for higher PDs. As we can see in figure 4.2.2, long-term credits (2 & 3 yrs) have declining maturity adjustment factor while precisely the opposite holds for short-term credits.

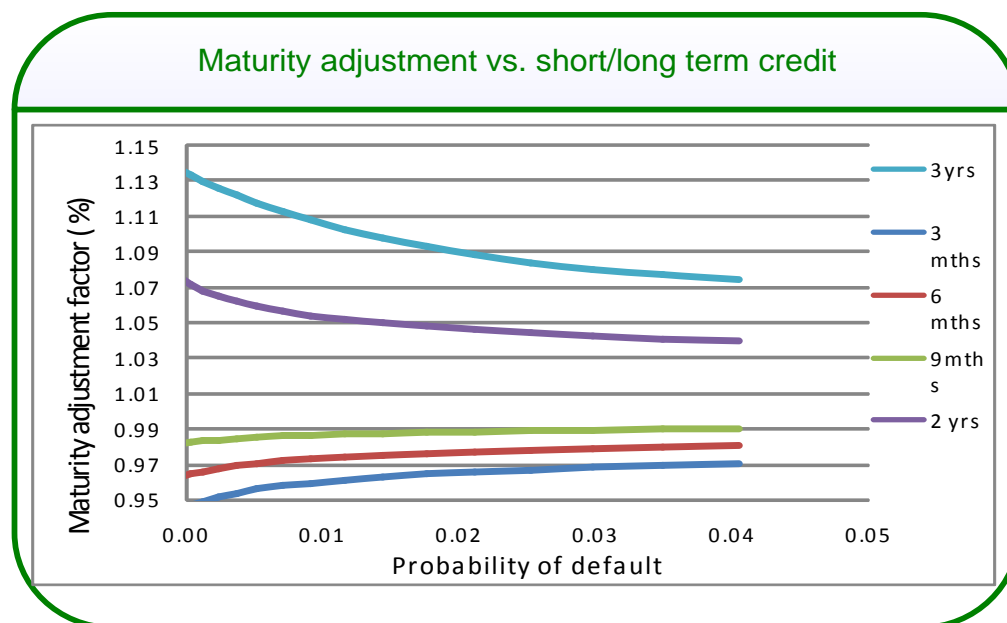


Figure 4.2.2: The maturity adjustment in capital function in relation with time

## 5 KMV-Merton Model

In section 4, we already discussed the **Regulatory Capital** model in detail. In section 4.1.2 we discussed the PDs which are one of the main ingredients in the Capital function. In this section we try to sketch how these PDs should be calculated in the real world using some well known forecasting models. The so-called **KMV** default forecasting model is one of these models based on Merton's bond pricing concept and is developed by the KMV Corporation [20]. Nowadays, this model has been intensively used by rating agencies such as Moody's ratings. To use this model the following three tasks have to be performed:

- I Estimate the asset value and asset volatility using historical or simulated data. Equity is a call option on asset value (Merton model).
- II Calculate distance to default (equation 5.1.6). Contractual obligations determine Default point.
- III Scale Distance to Default to Expected Default Frequency (equation 5.1.7).

Below we discuss these three steps separately.

In 1974 Robert Merton proposed a model for assessing the credit risk of a company by characterizing the company's equity as a call option in its assets [12]. The Merton model makes particularly two main assumptions:

The total value of a firm is assumed to follow Geometric Brownian motion [9].

$$dX_t = \mu X_t dt + \sigma_x X_t dW_t \quad (5.1.1)$$

Where the  $X_t$  is the total value of the firm at time  $t$ ,  $\mu$  (drift) is expected continuously compounded return on  $X_t$  and  $dW$  is a so called Standard Wiener process (*see appendix B*).

Suppose a firm has issued only one discount bond<sup>24</sup> maturing at  $T$  period (see figure 5.1) which pays no dividend and all the counterparts are operating in a so-called one factor economy<sup>25</sup>. In other words, the model considers a corporation financed through

<sup>24</sup> Zero coupon bond

<sup>25</sup> One factor economy consists of a market where labour is the only factor in production for each of the counterparties, supply is fixed in each country, perfect

a single loan and an equity issue. Further, it uses the European exercise term, before maturity it is not allowed to exercise the option. The market is assumed to be efficient, there is no arbitrage opportunity, no commissions are charged. The interest rate is known and treated as being constant.

Under these assumptions the firm's equity ( $E$ ) represents a call option on the underlying value of the firm with a strike price equal to the face value ( $F$ ) of the firm's debt with maturity  $T$ . Then  $E$  can be calculated with the famous Black-Scholes-Merton equation:

$$E = X * N(d_1) - e^{-rT} F * N(d_2) \quad (5.1.2)$$

Where,

$$d_1 = \frac{\ln(X / F) + (r + 0.5 * \sigma_x^2)T}{\sigma_x T^{(1/2)}} \quad (5.1.3)$$

$X$  = Total value time dependent

$e^{-rT} F$  = Discounted face value (strike price) of zero coupon bond with interest rate  $r$ ,

$\sigma_x^2$  = Firm's value spread,  $T$  = time to maturity,  $r$  = constant interest rate,

$$d_2 = d_1 - \sigma_x \sqrt{t},$$

$E$  = Market value of firm's equity,

$N(\cdot)$  = The cumulative standard normal distribution.

The main idea of the Merton model is that an obligor defaults when the asset level falls below its debt ( $F$ ) (see in [figure 5.1](#) and [5.2](#)) level. In that case an obligor or counterparty does not have enough money to repay his loans by selling his assets. [Figure 5.1](#) depicts the financial position of an obligor over time. The initial asset changes due to a volatile market, which can result in two scenarios. The first one is that the obligor defaults ( $E = (X_T - F) < 0$ ) (the lower part of the figure) and the second situation will be that the obligor has survived and is making profit ( $E = (X_T - F) > 0$ ), as seen in the upper part of the figure.

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competition prevails in all market and the productivity of each good is assumed to be the same.

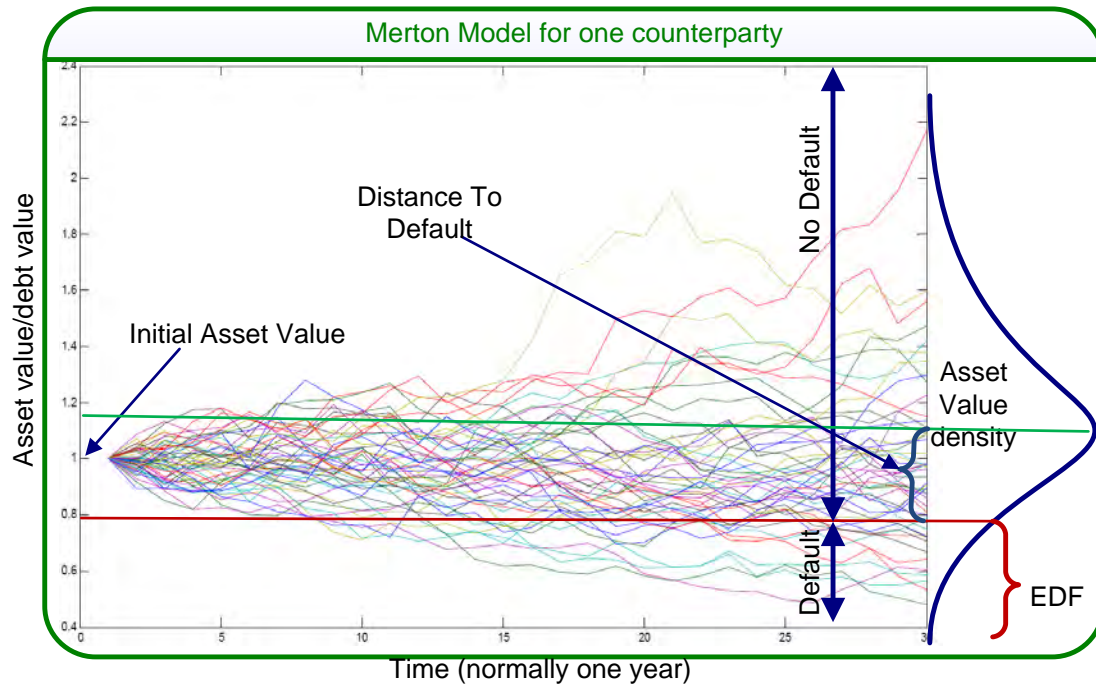


Figure 5.1: Merton model credit risk measure (one counterparty<sup>26</sup>).

Figure 5.2, depicted below, reflects the situation in which two obligors are involved. Of course, in practice the obligations from different counterparties are correlated and have significant impact in the total default risk [19]. As it is shown in figure 5.2, both obligors can default if their asset levels fall below their debt level and one of them can default when the asset level of one of them falls below its debt level [21].

<sup>26</sup> These data are „simulated data“ and are produced using the Geometric Brownian Motion (see [Appendix B](#)) in Excel. For further treatment I have used Matlab.

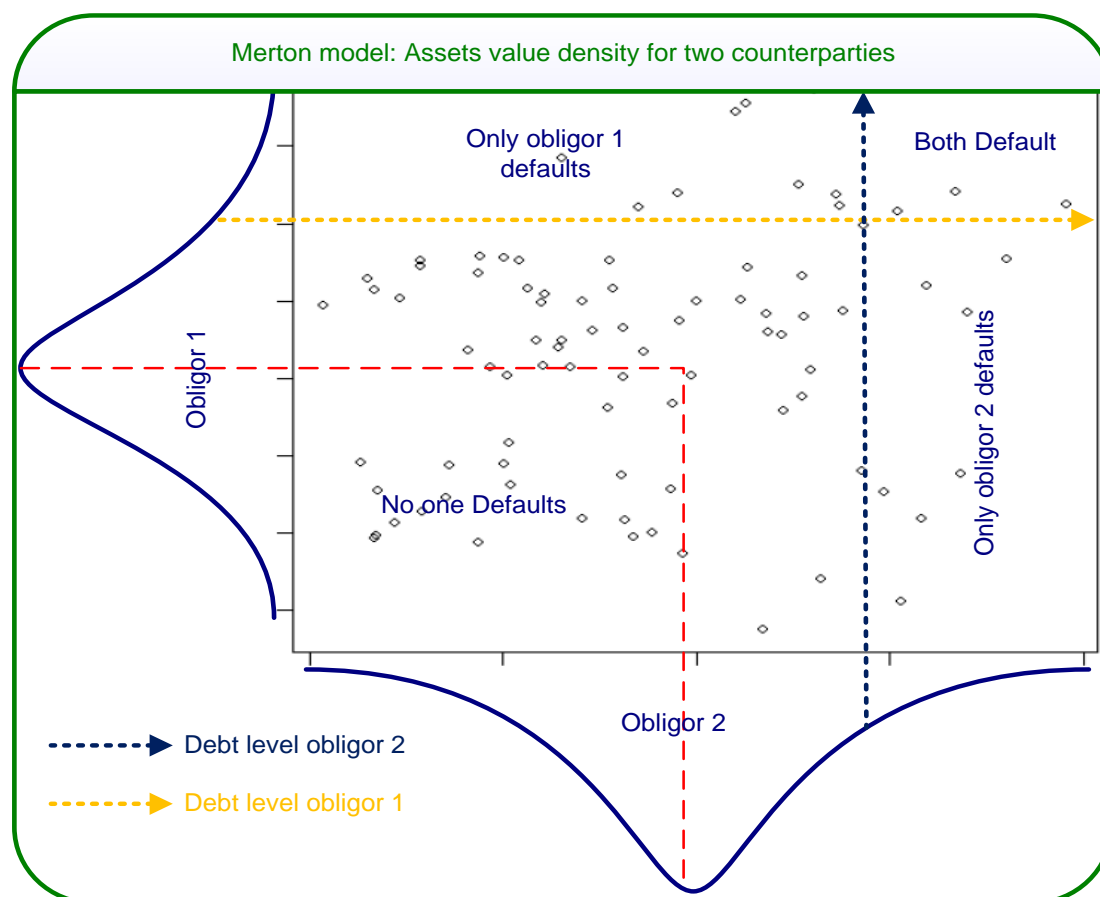


Figure 5.2: Portfolio distribution from two counterparties based on Merton model<sup>27</sup>.

In KMV-Merton default model the value of an option is observed as the total value of firm's equity while the value of underlying assets ( $X$ ) is not directly observable. In other words, only the prices of the equities for most public firms are directly observable. It can also be assumed, in many cases, that part of the firm's debt is also directly traded and necessary information is available. Thus, the firm's assets value  $X$  must be estimated while  $E$ <sup>28</sup> would be easy to get<sup>29</sup>, and in the same manner  $\sigma_E$ <sup>30</sup> would also be easy to get while  $\sigma_X$  would need to be inferred. Assuming a forecasting horizon of one year and taking the book value of firm's total liabilities to be the face value ( $F$ ) the only things remained are values of risk free rate and the market equity of the firm to estimate firm's value  $X$  and its volatility. However, the

<sup>27</sup> These data were simulated using Geometric Brownian Motion. The figures then can be plotted using some statistical software like R or Matlab.

<sup>28</sup>  $E = \text{Nr. Of outstanding shares} \times \text{current stock price}$

<sup>29</sup> Actually, in most of the applications, the Black-scholes model describes the unobserved value of an option as a function of four variables - strike price, maturity time, underlying asset price, risk free interest rate and one variable that can be estimated (volatility).

<sup>30</sup> Using historical data we can calculate this one.

assets volatility can estimated either from historical data or using option pricing model. The risk free rate is also observable factor in the market.

While estimating the default probabilities the KMV model<sup>31</sup> makes mainly two assumptions: the firm's equity is the function of firm's value (related through equation (5.1.2)) and the equity volatility relate the value volatility, which can be given by Ito lemma (5.1.4). The KMV-Merton model uses these equations, (5.1.2) and (5.1.5), to transform the firm's equity and volatility of firm's equity into **implied default probability**<sup>32</sup>.

In other words, our equity function based on option pricing approach (equation (5.1.2)) is:  $E = f(X, \sigma_x, F, T, r)$ <sup>33</sup> and its volatility function can be expressed as:  $\sigma_E = g(X, \sigma_x, F, T, r)$ . Since firm's equity and its volatility are easy to get (implied or from historical data), we can apply equity volatility equation (Ito lemma (5.1.4) to derive the underlying asset's volatility,  $\sigma_x$ . To estimate the equity volatility we have the following expression [24].

$$\sigma_E = \sigma_x \left( \frac{X}{E} \right) * \left( \frac{\partial E}{\partial X} \right) \quad (5.1.4)$$

Then the time dependent firm's value volatility is:

$$\sigma_x = \left( \frac{E}{X} \right) * \sigma_E * \left( \frac{\partial E}{\partial X} \right)^{-1} \quad (5.1.5)$$

Once this numerical solution is obtained we can calculate so-called distance to default (DD) [20]:

$$DD = \frac{\ln\left(\frac{X}{F}\right) + (\mu - 0.5\sigma_x^2)T}{\sigma_x \sqrt{T}} \quad (5.1.6)$$

Where,  $\mu$  denotes firm's assets annual return and  $\ln(\cdot)$  is natural logarithm number.

Then the corresponding implied probability of default (known as Expected Default Frequency (EDF)<sup>34</sup>) can be given as follow (see figure 5.1 also):

<sup>31</sup> One popular implementation of Merton model is so-called KMV-Merton model which is now owned and used by Moody's rating agency.

<sup>32</sup> Implied default probability of a portfolio is the probability implied by the market development of that portfolio based on some pricing model.

<sup>33</sup> Here,  $X$  is time dependent firm's value,  $\sigma_x$  is asset volatility,  $F$  stands for firm's liabilities,  $T$  is time horizon and  $r$  represents the risk free interest rate in the market.

<sup>34</sup> Expected default frequency is mostly calculated for a period of one year.



$$\text{KMV-Merton Probability} = \pi \text{KMV} = N \left( - \left\{ \frac{\ln \left( \frac{X}{F} \right) + (\mu - 0.5\sigma_x^2)T}{\sigma_x \sqrt{T}} \right\} \right) \quad (5.1.7)$$

Using this equation we will be able to estimate one of the main components, the probability of default, embedded in capital function.

### 5.1 Credit Default Model: Basel Concept

In the previous section we discussed an example of a credit risk default model, the KMV model, based on the Merton concept. In section 4 we also presented the Basel II capital requirement model and discussed its components in detail. This section is an extension of the preceding section. As stated earlier the Basel II capital requirement function is based on the one factor model. In this section we discuss the Basel II capital requirement function and the credit risk default model embedded in it (*see equation 4.1.9*). Let us repeat the capital requirement equation from equation (4.1.9):

$$K(PD, LGD, M) = \left\{ \frac{1 + b(PD)(M - 2.5)}{1 - 1.5 \cdot b(PD)} \times LGD \times \Phi \left( \frac{\Phi^{-1}(PD) + \Phi^{-1}(0.999) \sqrt{\rho(PD)}}{\sqrt{1 - \rho(PD)}} \right) \right\} \quad (5.1.8)$$

If we look at the above equation we can observe three main components embedded in it: PD, LGD and M. Here below, we discuss how the PD component can be derived.

We make the following assumptions in advanced:

- The numbers of obligor are very large;
- Diversification plays a great role and the exposure size is equal to 1/n for all the counterparties, so if the number of counterparts tends to infinity the exposure would also tend to zero;
- All obligors have the same probability of default, p, and the asset value of all obligors follows a Gaussian process (*see appendix C*) with independent and identically distributed variables.

In section 4.1.1 we discussed the ASRF model. We can now extend equations (4.1.2) and (4.1.3) for this example. Let us assume that an obligor defaults if its return  $Y_i$  falls

below the default threshold  $\gamma$  and the asset value for all obligors follows a Gaussian process with [23]  $Y_i = \varepsilon_i \sqrt{1 - \rho} - X \sqrt{\rho} \leq \gamma_i = \Phi^{-1}(PD_i)^{35}$ ,

$X \equiv N(0, 1)$  systematic risk factor

$\varepsilon_i \equiv N(0, 1)$  idiosyncratic risk factor

$\rho \equiv$  asset correlation

The default probability distribution function conditional on realization of the systematic factors can be defined as [23]:

$$PD(x) = \Phi \left\{ \frac{\Phi^{-1}(\rho) - \rho \times x}{\sqrt{1 - \rho^2}} \right\} \quad (5.1.9)$$

With  $E[PD(x)] = PD$  and  $\text{var}[PD(x)] = E[(PD(x))^2] - PD^2$

And the conditional expected loss function for exposure  $i$  given  $X$  is given by:

$$\left\{ \begin{aligned} c_i(x) &= \Pr[Y_i \leq \gamma | x] \cdot LGD_i \\ &= \Pr[\varepsilon_i \sqrt{1 - \rho} - X \sqrt{\rho} \leq \Phi^{-1}(PD_i) | x] \cdot LGD_i \\ &= \Phi \left( \frac{\Phi^{-1}(PD_i) + x \sqrt{\rho}}{\sqrt{1 - \rho}} \right) \cdot LGD_i \end{aligned} \right\} \quad (5.1.10)$$

If we add the maturity part and plug the 99% percentile of  $X$  in equation (5.1.9) we will get the following expression:

$$k(PD, LGD, M) = \left\{ \begin{aligned} &\frac{1 + b(PD)(M - 2.5)}{1 - 1.5 \cdot b(PD)} \times LGD \\ &\times \Phi \left( \frac{\Phi^{-1}(PD) + \Phi^{-1}(0.999) \sqrt{\rho}}{\sqrt{1 - \rho}} \right) \end{aligned} \right\} \quad (5.1.11)$$

In the next section we present various plots for the above function which may explain the relation among different components in the Capital requirement function.

<sup>35</sup>  $Y_i = \varepsilon_i \sqrt{1 - \rho} - X \sqrt{\rho}$  represents the asset value process [6]. For technical details we recommend „Asset Return Correlations in Basel II: Implication for Credit Risk management“ by - Marie-Paule Laurent.

## 6 Soundness of capital requirement Basel II

In this section we discuss the soundness of the capital requirement under Basel II in relation to asset correlations, LGD, PDs and maturity adjustment [6].

### 6.1 Assets Correlation vs. Capital Requirement

Market has a complex phenomenon where various financial sectors are related to each other. Financial products within one sector are mostly affected by changes in other sectors. Altogether, we can describe this situation as the dependence of the asset value of an obligor on the general state of the economy [7]. Correlation<sup>36</sup> is a single factor which reflects how the various obligors in the market are related to each other. Basel II accord uses the different correlation for different assets to assess the capital requirement though they are prematurely fixed depending on the kind of assets (see *section 4.2*). Figure 6.1.1 represents the default probability mass function with different assets correlations [19]. If we look at it we can observe the smooth change in distribution shape (*see figure 6.1.1*), the larger the correlation the more asymmetric the distribution function. This also implies that the higher the correlation the higher the default credit risk. Including negatively correlated assets in the portfolio therefore reduces the default risk considerably.

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<sup>36</sup> The correlation, also called correlation coefficient, indicates the strength and direction of a linear relationship between two random variables. When two variables are assumed to be correlated they are also dependent of each other. In the financial world it is preferred to include various assets in a portfolio which are independent of each other. In other word, to minimize the risk one should take less correlated assets in the portfolio. When assets are negatively correlated the assets in the portfolio have a hedging effect.

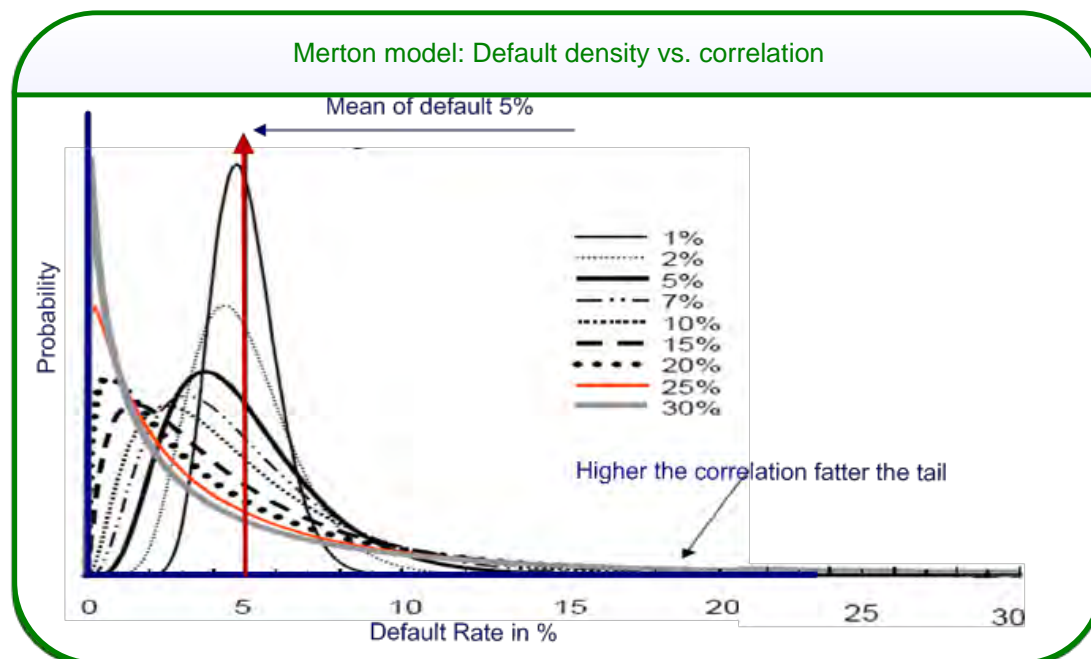


Figure 6.1.1: The higher the correlations the fatter the tails (extreme default values).

While stipulating the credit risks under the IRB approach Basel II supervisory committee (2001, CP2) had made two main assumptions: the 20% assumption for assets correlations and the one factor assumption. This assumption was modified in CP3 to the assumption that the correlations are mainly based on PDs.

Figure 6.1.2 plots the equations (4.2.1) for different options (equation 4.2.2) which shows the relationship between correlations and PD rates for different asset exposures. Though it is difficult to observe, the small firms have higher correlations with increasing PDs at the end. This is because the PDs for smaller enterprises are assumed to be higher. Besides that, the pace in which the correlation function decreases is determined by the so-called „K“ factor. So, for corporate exposures it is set to 50 (equation (4.2.3)) and for retail exposures is set to 35 (equation (4.2.4)).

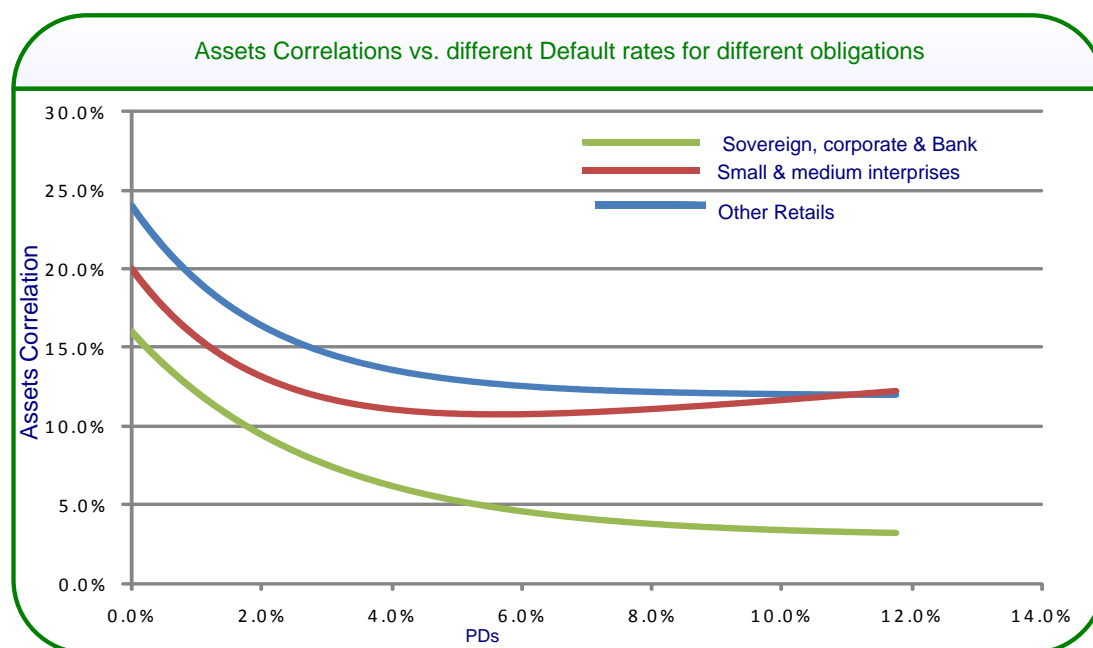


Figure 6.1.2: The assets correlations and the default rate for different obligation categories

When we compare the different default distributions, with each obligor having 5% default rate on average (meaning that the average default rate for each obligor is 5%), belonging to different asset correlations, we can observe the variation in the capital requirement.

Basel II used a 99.5% confidence interval while assessing the default rates in the past. This has now been changed to 99.9% to protect against errors and model uncertainties while occurring from PD, LGD, and EAD [13]. Measuring the capital requirement it is necessary to look at the maximum capital loss for a given confidence level (*see Appendix D*). Technically speaking this capital is the amount equal to some defined percentile of the defaults distribution. The 99.9% confidence interval used by the supervisory committee for capital requirement assessment seems to be quite general in form. As all the default rates are dependent on the asset correlations it shouldn't be fair to use one standard confidence level, which should rather change with the asset's type and correlations. For example, the default rate should be different when we have assets with 7% or 20% correlation with the same 99% confidence level. Table 6.1 summarizes the relationship among confidence level, asset correlation and default percentiles. Compared to the findings with the Basel II data we can conclude that the Basel II capital requirement formulation is not precise.

	Confidence level	Asset Correlation	Default rate
Obligor 1	99%	7.5%	14.5%
Obligor 2	99%	10%	17.5%
Obligor 3	99%	20%	25.4%
Obligor 4	99%	30%	35%

Table 6.1: Influence of asset correlation on the percentiles (default rates) is considerable

All in all, we can conclude that the default rates are very sensitive to the assets correlations and the PDs confidence level. To maximize the soundness of the capital requirement one should be very strict while estimating these components.

## 6.2 LGD and capital requirement

As we previously observed, the LGD is one of the important components in the regulatory capital function. Here we attempt to show how LGD is embedded in the Capital Requirement assessment and its impact on the overall capital requirement [13]. Basel II recommends using a constant LGD based on supervisory values. For instance, 45% for unsecured claims<sup>37</sup> and 75% for subordinated claims<sup>38</sup>. Juan Carlos (spring 2002) has shown that the constant LGD set by the Basel supervisory committee varies considerably with the type of credit assets. This implies the constant LGDs will prevent providing real required capital. We can prove this argument through plotting the following function (from equation (5.1.11)) [8]:

$$RC = LGD \cdot \Phi \left( \frac{\Phi^{-1}(PD_i) + \Phi^{-1}(0.999)\sqrt{\rho}}{\sqrt{1-\rho}} \right) \quad (6.2.1)$$

Where,

$RC$  = regulatory capital

$LGD$  = Loss given default

$\rho$  = Assets correlations

$\Phi^{-1}(\rho)$  = The inverse cumulative distributions function for a standard normal random variable (correlation)

$\Phi(\rho)$  = The cumulative normal distributions function for standard random variables (correlation).

<sup>37</sup> These credits have priority of getting paid in first in the case of bankruptcy.

<sup>38</sup> These claims don't get paid until other unsecured creditors have been paid in full.

Plotting the required capital equation (6.2.1) with respect to EL and LGD we get figure 6.2.1. Here we take constant asset correlations of 20%, along with a 99.9% confidence interval as applied by the Basel model:

$$RC = LGD \cdot \Phi \left\{ \frac{\Phi^{-1}(PD_i)}{\sqrt{1-0.2}} + \frac{\sqrt{0.2} \Phi^{-1}(99.9)}{\sqrt{1-0.2}} \right\} \quad (6.2.2)$$

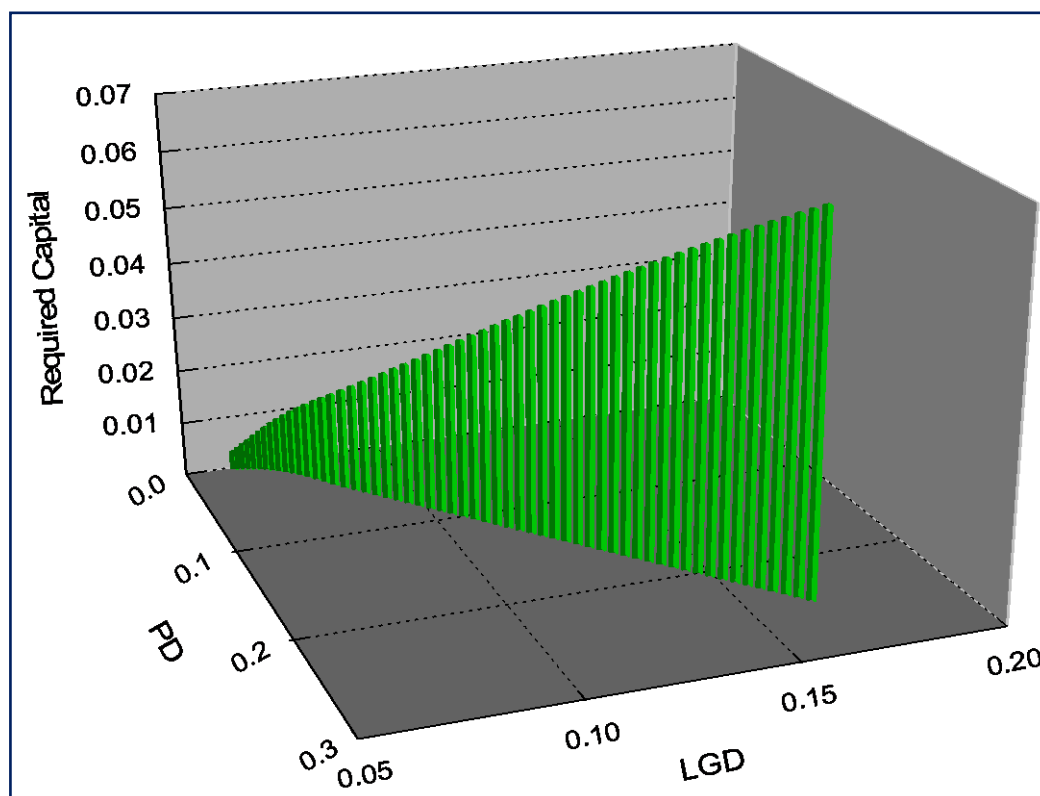


Figure 6.2.1: RC as function of LGD and PD (see [Appendix F](#))

In figure 6.2.1 we can observe that changes in RC are quite proportional to changes in LGDs and PDs. These changes occur on a continuous basis rather than by some constant rate. Moreover, in section 4.1.5, we stated that Basel II requests the banks to provide the downturn LGD which is supposed to reflect the tendency of general LGD for economic downturn. Basel II doesn't contain an explicit function which transforms the average LGDs, estimated to happen under normal market condition, to conditional LGDs that are based on the conservative value of the systematic factor. So, the proposed LGDs might fail to represent real situation and will provide wrong indication for the required capital.

All in all, the capital requirement function provided by Basel II still shows many shortcomings. To provide robust and bank specific required capital Basel II may need to provide better methods for distinctive components estimation.



## 7 Conclusion

This paper puts emphasis on the AIRB approach proposed by the Basel II agreement for the minimum capital requirement. We discussed among others the regulatory function and its components. At the end some empirical research is applied to support the pros and cons of the capital function.

The Basel committee on banking supervision was established in 1974 by the central banks governors of the G-10 countries. The main objective of this institution is to establish soundness in financial banking system through the laying down of financial rules and establishment of specific rules of behaviour, monitoring whether the rules are obeyed and keeping more general oversight of a financial firm's behaviour. To guarantee the robustness and to prevent monopolistic exploitation, asymmetric information and other externalities problems within the banking system the committee has established among others the minimum capital requirement norm. The Basel I accord was seen as an incapable and outdated version since there were many shortcomings such as the „arbitrage benefit“ , the committee decided in 1998 to modify Basel I to the Basel II accord. Basel II has responsibilities to monitor, supervise and to setup a comprehensive financial regulation framework. The core objective of Basel II is however to reduce banking market disturbances by setting up a comprehensive framework for recognizing and assessing various risks. To achieve this goal Basel II activities are divided in three pillars: minimum capital requirement, supervisory review process and market discipline. To assess the minimum capital requirement Basel II purposed two approaches: the standardized approach and the IRB approach. The IRB approach relies heavily upon a banks internal assessment of its counterparties and exposures, allows banks to choose a suitable method to assign the risks remaining within the supervision criterion. According to this method the banks are supposed to provide information such as PDs, LGD and EAD from issued credit which later can be used for assessment of the minimum capital requirement. Since banks can't exactly estimate their credit risk in advance beside the regulatory capital they used to create different reserves like economic capital for internal safety (zin loopt niet?).

The regulatory capital requirement (CR) function proposed by Basel II is based on the so called ASRF Merton model. While using the CR function Basel II assumes that the model should be invariant, meaning that the capital required for any loan should

depend only on its own risk and shouldn't be affected by the portfolio added to it. As Gordy (2003) has shown only the Asymptotic Single Factor (ASRF) model can be portfolio invariant, Basel II decided to include this idea in the capital function. The main idea of the ASRF model is when a portfolio consists of infinitely large numbers of relatively small exposures the idiosyncratic risk can be completely diversified away and only the systematic risk (only one risk exposure factor) will remain.

Various components imbedded in the capital function such as PDs, LGD and EAD can be calculated using the Merton model or another similar model. The core idea of the Merton model is that one obligor defaults when its equity falls below its debt level and the banks can't reclaim its loans anymore. To provide an idea about how PDs could be calculated we discussed the KMV credit risk model. The KMV model, a commercial technique for credit risk modelling, is discussed in the context of the Merton model. As this model is based on the Black-Scholes option pricing model we discussed these terms and their technical details. We also discussed the Basel credit risk modelling concept based on the Merton model .

The last part of this paper discussed the soundness of the capital requirement function in relation to asset correlations, maturity adjustment and LGDs. For the sake of simplicity Basel II uses fixed correlations for different assets depending on their level of risk. Our results have shown that only continuous maturity adjustment can provide the precise capital requirement. Not only for maturity adjustment but also for LGD and asset correlations it is necessary to use smooth adjustments rather than the fixed ones to be able to assess the precise Regulatory Capital Requirement.

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## 9 Appendixes

### **Appendix A:**

#### **Standard & Poor's Credit Ratings**

AAA These corporations have the credit quality and they are financially extremely reliable.

AA These corporations are known as having very good credit quality and reliable as well.

A corporations can be easily be influenced by outside elements but they have still very good credit quality.

BBB These are graded very low in investment.

BB Caution is necessary time to time but they have best sub-investment credit quality.

B Are vulnerable to changes in economic condition and market in general, but currently enough capacity to meet all financial obligations.

CCC These corporations are really vulnerable for non-payment obligations and are dependent on favourable economic condition in market.

CC These are extremely vulnerable for non-payment and not being able to get financial support anymore from lenders.

C Close to or already bank-corrupt and possible default payments currently continued.

D Default payments on some financial obligations are widely shortcoming.

## Appendix B

### Brief technical explanation: Brownian motion & GBM

Stochastic process:

A continuous-time stochastic process is a collection of random variables  $X = (X_t : t \geq 0)$ , defined in a given probability space  $\Omega$ . Thus, every  $X_t$  is a map  $X_t : \Omega \rightarrow \mathbb{R}$  which maps  $\omega \in \Omega$  into numbers  $X_t(\omega)$  and function  $t \rightarrow X_t(\omega)$  attached to the outcomes are called the sample path which should be limited in  $[0, \infty)$ .

Brownian motion (BM):

Weiner process (Brownian motion),  $W_t$  is a special stochastic process which is characterized with the following three facts:

At  $t = 0$  holds  $W_t = 0$ ;

$W_t$  is almost surely continuous;

$W_t$  has independent increments with the distribution  $W_t - W_s \sim N(0, t - s)$  (for  $0 \leq s \leq t$ )

NB: A stochastic process defined by  $X_t = \mu t + \sigma W_t$  is called a Weiner process with drift  $\mu$  and infinitesimal variance  $\sigma^2$ .

Since the general Brownian motion, at time  $t$ , is assumed to be normally distributed with expectation zero it takes negative value with 50% probability. Since in the financial world it is unimaginable to have negative assets prices, some adjustment should be necessary to be able to apply the BM for assets prices evolution.

Thus, the so called Geometric Brownian motion (GBM), also called Exponential Brownian motion, is being used to replicate the real assets price (mostly in option pricing) evolution in the market. This can be expressed in the form:  $e^{(W_t + \alpha + \beta t)}$ .

Say, a stochastic process which follows the GBM is assumed satisfy the following Stochastic Differential Equation:  $dX_t = \mu X_t dt + \sigma X_t dW_t$

The GBM equation finally has the following analytical solution with some arbitrary initial value  $S_0$  :

$X_t = X_0 \text{EXP} \left\{ \frac{(\mu - \sigma^2)}{2} * t + \sigma W_t \right\}$ , which is used to simulate the assets prices data included in this paper!

**Appendix C**

**Technical details Gaussian (normal) Distribution**

A random variable  $X = x_1, x_2 \dots x_n$  is said to have Gaussian distribution if its distribution function takes the following form:

$$f(x; \mu, \sigma) = \frac{1}{\sigma\sqrt{2\pi}} \exp\left\{-\frac{(x - \mu)^2}{2\sigma^2}\right\}$$

Where the  $\mu=0$  is location parameter and the  $\rho=1$  scale parameter.

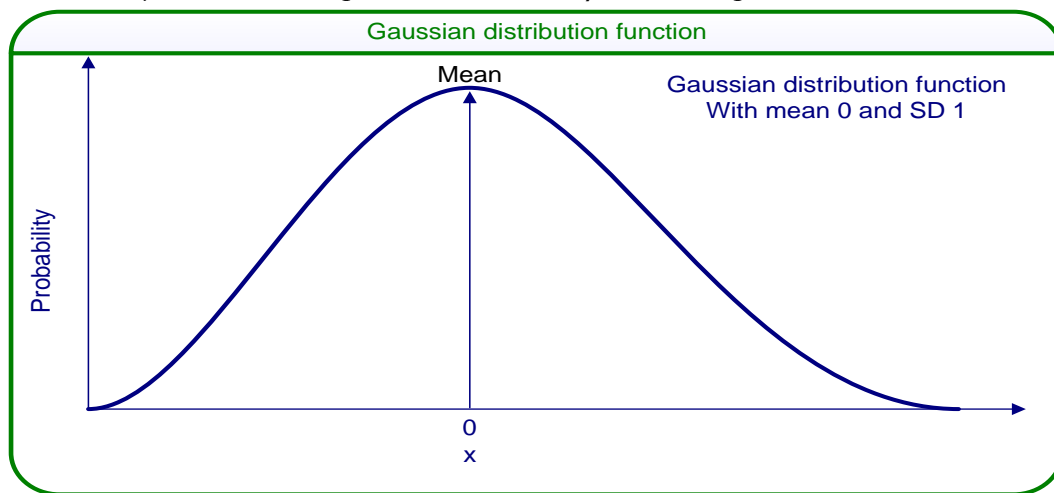


Figure B1: Standard normal density function

The formula for the cumulative distribution function doesn't exist in closed form. It is calculated numerically and this can be done with:

$$f(x; \mu, \sigma) = \frac{1}{\sigma\sqrt{2\pi}} \int_{-\infty}^x \exp\left\{-\frac{(u - \mu)^2}{2\sigma^2}\right\} du$$

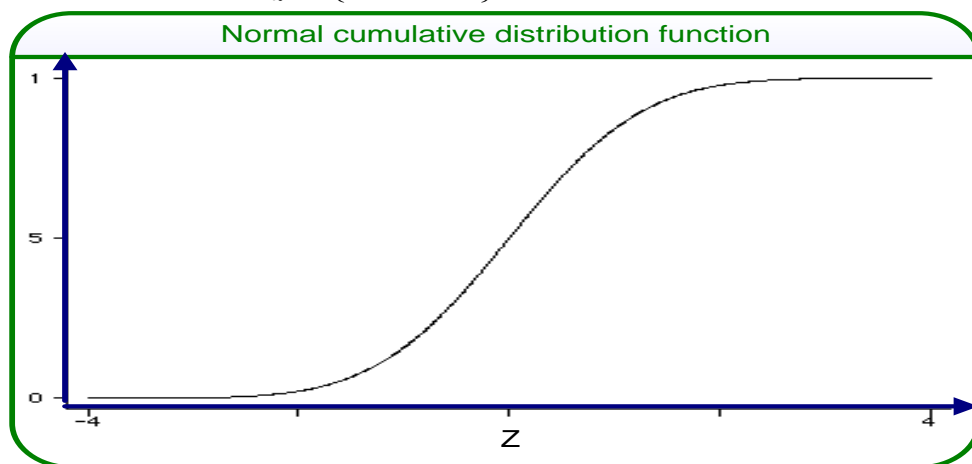


Figure B2: Cumulative normal distribution function



**Appendix D**

**Correlations, confidence interval and PDs**

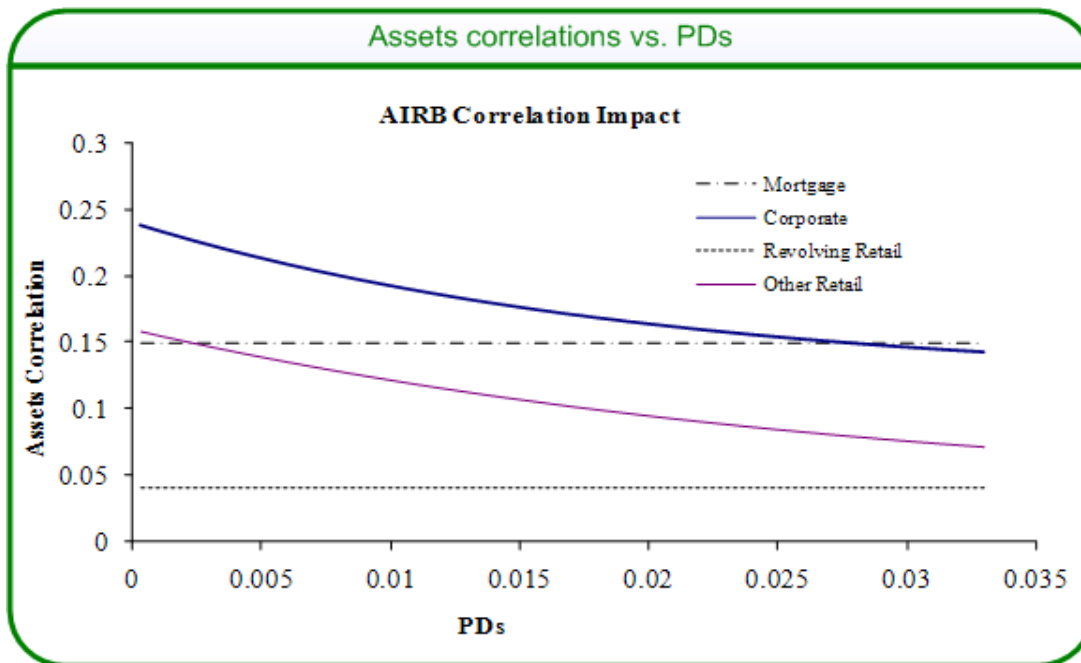


Figure D1: Mortgage and Revolving retails have constant correlation.

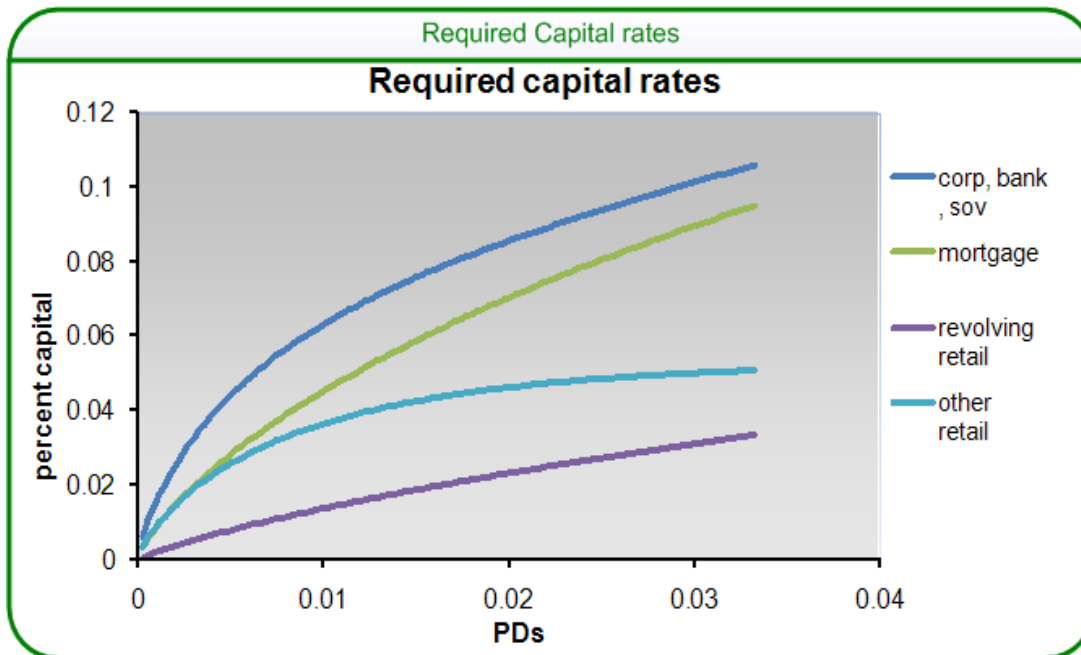


Figure D2: Required Capital depends on assets group and assets category

**Appendix E**

Required Capital, LGD, PDs

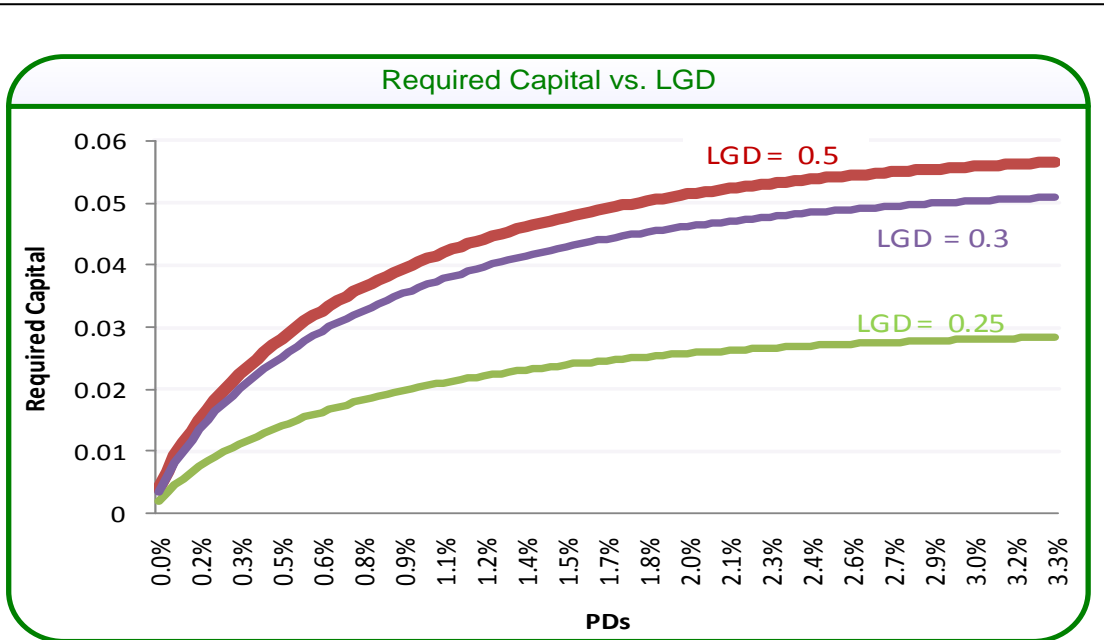


Figure E1: Required Capital changes with variation in LGD

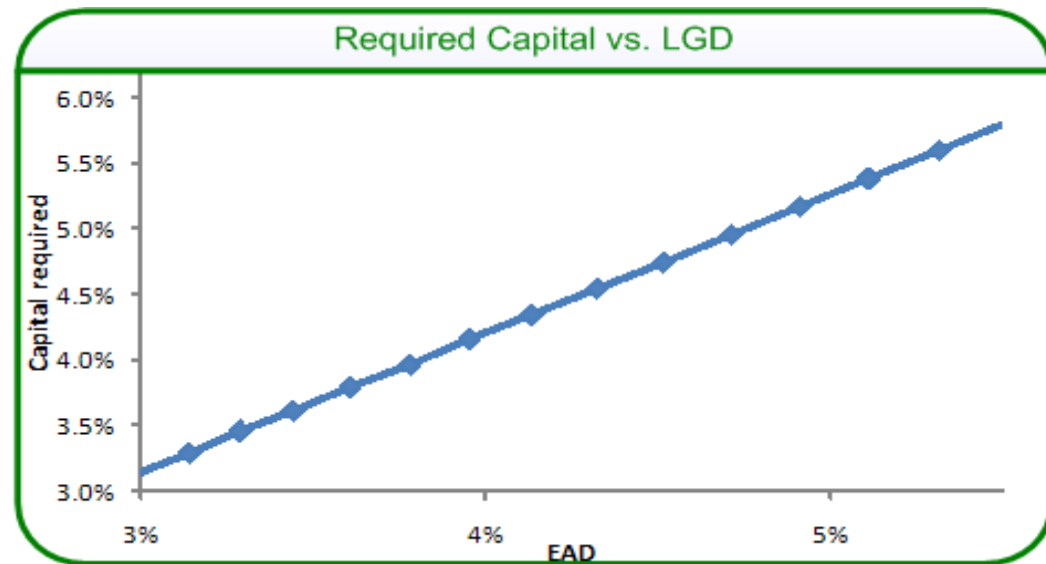


Figure E2: Required Capital vs. EAD

***Appendix E: continue***

Plotting Maturity Adjustment vs. PDs, EAD, Correlations & Required Capital

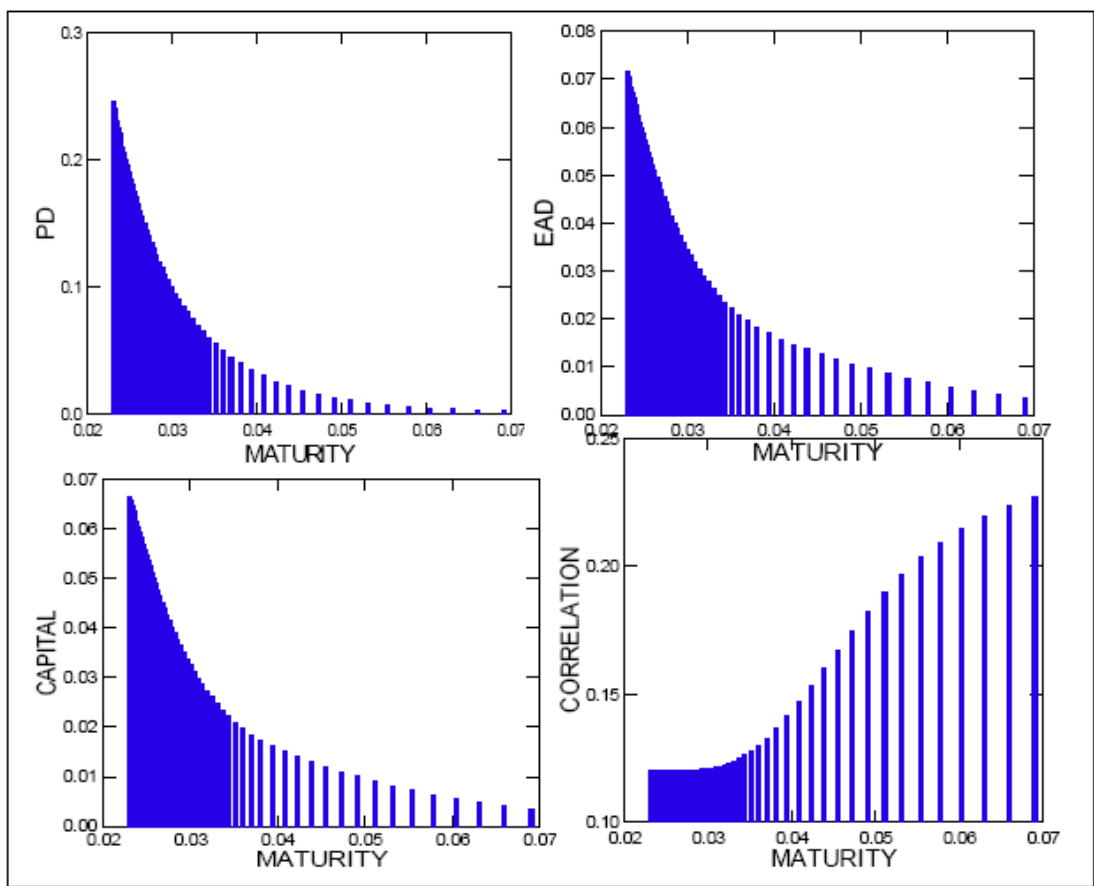


Figure E3: Maturity vs. others components<sup>39</sup>

<sup>39</sup> Values for other components are also varying at the same time.

**Appendix F**

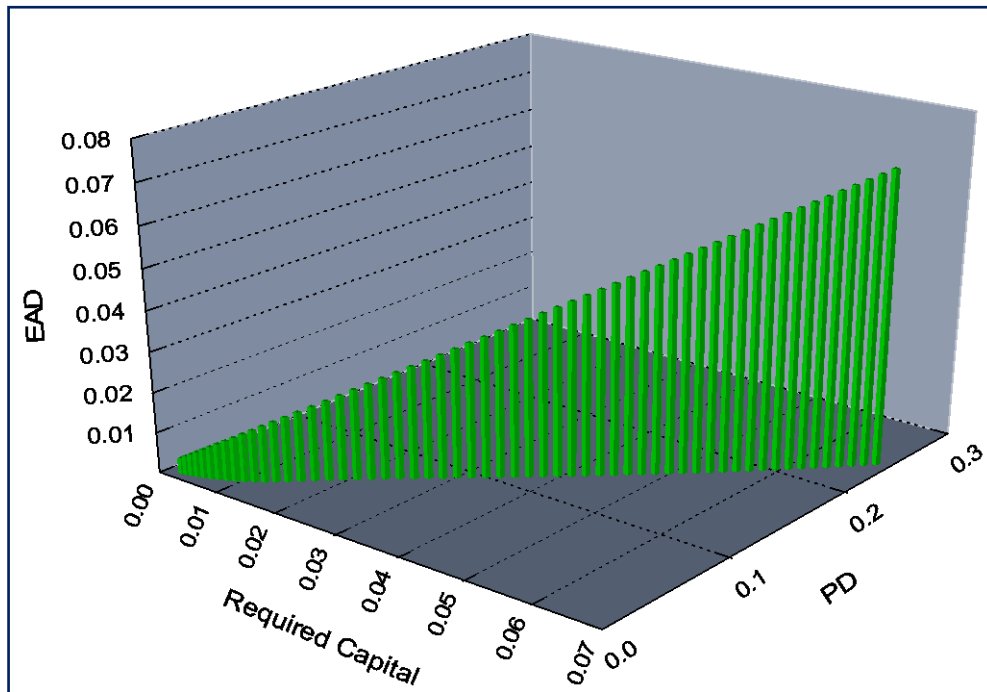


Figure F1: Required Capital vs. PDs & EAD

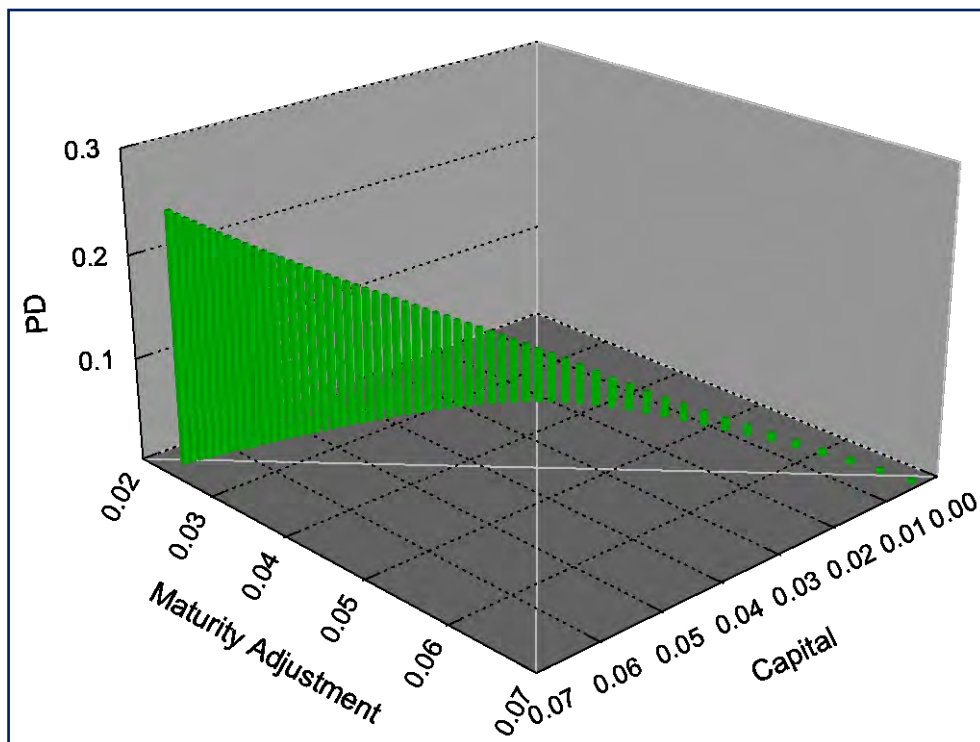


Figure F2: Required Capital vs. PDs & Maturity Adjustment