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FUNDAMENTAL REVIEW OF THE TRADING BOOK

THE NEW APPROACH TO MEASURE MARKET RISK

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Abstract

The Fundamental Review of the Trading Book sets the standard for the most recent regulatory framework for minimum capital requirement within market risk. It will be implemented gradually up until 2019 and will overhaul a major part of the current regulation. More specifically it will cause financial institutions to estimate risk with Expected Shortfall instead of Value-at-Risk and add a new way of treating varying liquidity among assets.

This research looks into the new framework by evaluating three different indices. The values of Expected Shortfall and Value-at-Risk are compared and possible effects that the new framework has on minimum capital requirement for market risk are explored. To estimate risk, both parametric estimation approaches as well as a non-parametric estimation approach are utilized. In order to calculate the minimum capital requirement, the regulatory framework set out by the Basel Committee on Banking Supervision is utilized. To evaluate the changes in the regulatory framework of the Fundamental Review of the Trading Book we compare it with the previous regulations Basel I, Basel II and Basel II.5.

The study finds evidence for the change of risk measure having an impact on the estimated riskiness of the evaluated assets. What the study finds to be seemingly most important in the new regulatory framework is the inclusion of varying liquidity horizons. Evidence for longer liquidity horizons causing the capital requirement to increase relative to previous regulation is presented. Finally, the minimum capital requirement under the Fundamental Review of the Trading Book show apparent signs of being less pro-cyclical.

Keywords: Expected Shortfall, Value-at-Risk, Fundamental Review of the Trading Book, Bank for International Settlements, Basel Committee on Banking Supervision, Market risk, Parametric approach, Non-parametric approach

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LIST OF ABBREVIATIONS

BCBS : Basel Committee on Banking Supervision

BIS : Bank for International Settlements

EWMA : Exponentially Weighted Moving Average

FRTB : Fundamental Review of the Trading Book

ES : Expected Shortfall

HS : Historical Simulation

IMA : Internal Models Approach

SA : Standardized Approach

sES : Stressed Expected Shortfall

sVaR : Stressed Value-at-Risk

VaR : Value-at-Risk

IMCC : Internally Modeled Capital Charge

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CHAPTER 1: INTRODUCTION

1.1 BACKGROUND

The Basel committee on Banking Supervision was founded in 1974 as a reaction to instabilities in currency and banking markets with the goal to improve banking supervision globally (BIS, 2016a). Goodheart (2012) explains that the Basel Committee on Banking Supervision (BCBS) was founded mainly due to growing globalization of financial intermediation. Bank for International Settlements (2016a) explains that initially, governors from 10 different nation's central banks made up the committee and today the number has grown to consist of members from 28 different jurisdictions.

Bank for International Settlements (2011a) states that the financial institutions which are controlled by the Basel regulation constitutes of all internationally active banks. These will be referred to as financial institutions throughout this thesis.

Since the Basel committee was founded three major publications have been brought forward regarding capital adequacy in financial institutions, namely Basel I, Basel II and Basel III (BIS, 2016a). In May 2012 a new document was published by the BCBS, named the Fundamental Review of the Trading Book which aims to strengthen capital standards for market risk even further (BIS, 2012). Market risk is defined as the risk of losses in the balance sheet, both off and on positions, arising from opposing movements in market prices (EBA, 2017).

According to Bank for International Settlements (2012), The Fundamental Review of the Trading Book will overhaul previous regulation for determining market risk capital. Instead of Value-at-Risk (VaR) being the basis for capital requirement calculations, the new regulation will instead rely on Expected Shortfall (ES). In short, Value-at-Risk determines the potential for big losses with a set confidence interval, whereas ES is the average of these losses over the set confidence level. Value-at-Risk does not concern for the specific amount in the loss over this confidence level meanwhile ES does, which as the recent financial crisis showed, makes a vast impact regarding risk management (BIS, 2014). The change of risk measure is due to the weaknesses that Value-at-Risk has been found to exhibit. Hull (2015) explains that instead of a Value-at-Risk measure with a 99 % confidence level Expected Shortfall will be calculated using a confidence level of 97.5 %. This calculation will form the basis for market risk capital.

During the recent crisis it became apparent that all positions in the trading book, where market risk is traded, were in fact not as liquid as they were treated and that regulatory capital has to be sufficient during periods of stress. Due to this the FRTB will include varying liquidity horizons for different positions which differs from previous regulations where all positions were treated as equally liquid (BIS, 2012). This means that the current regulation which assumes that all positions have a 10-day liquidity horizon will be replaced by incorporating different liquidity horizons that varies depending on the traded instrument (BIS, 2016b). In addition to this, Expected Shortfall has to be calibrated to a stressed period for the held portfolio in question. This calibration aims to reduce the cyclicality of the minimum requirement for market capital that is seen empirically (BIS, 2012). As of today Basel III is the current framework for credit risk. Simultaneously there exists a framework for market risk, Basel II.5 that is now in transition into the new framework, The Fundamental Review of The Trading Book (The FRTB) which is gradually implemented until year 2019 (BIS, 2016b).

1.2 PREVIOUS RESEARCH

According to the Bank for International Settlements (2014) some issues concerning the new regulation have arisen. Banks have used a variety of different approaches to calculate Expected Shortfall (from now on referred to as ES) and many have found it challenging to implement the new amendment of liquidity horizons. Along with this there have been uncertainties in how to determine if a risk factor is non-modelable or not. If a risk factor is non-modelable there are no available "real" prices on the asset, most commonly when the asset has less than 24 observations per year. The non-modelable risk factor is then adjusted to project at least as conservative values as the ES calibration used in a financial institutions internal model. These are later summed up in order to give a total capital charge for the non-modelable risks.

The Basel committee (2014) ran tests through a hypothetical portfolio exercise where they used the Internal Model Approach (from now on referred to as IMA), which determines the minimum capital requirement, to better understand the impact of the FRTB. The main objective with performing the hypothetical portfolio exercise was to gain an understanding of the different challenges that could be associated with the FRTB, more specifically with the IMA. The Basel committee performed tests together with internationally active banks that were already using the IMA to estimate risk. Banks that only partially traded the different categories (equity, commodities, FX, interest rate and credit spread) were still encouraged to participate since these were all likely to be affected in some manner by the FRTB. In their research they state that the FRTB will cause financial institutions to move to a single risk measure which is calculated at a lower confidence level compared to the current regulation. This particular change is likely to cause the capital to decrease. At the same time the new risk measure averages the tail of the distribution and includes longer liquidity horizons. Both these latter mentioned changes are expected to cause the capital to increase.

In a recent study by Bank for International Settlements (2015) it was found that the market risk capital will increase under the proposed new regulation. In an impact analysis where 44 banks where evaluated the internally modeled market risk capital was on average 54% higher compared to the current regulation.

Hull (2015) states that a Value-at-Risk (from now on referred to as VaR) measure with a confidence level of 99 % will approximately be equal to Expected Shortfall with a 97.5 % confidence level under a normal distribution. He however points out that the ES can be larger under a distribution with heavier tails. Dowd (2005) points out that empirical returns often have heavy tails, where Fama (1965) adds to this and argues that there is empirical evidence for financial data not being normally distributed.

1.3 PURPOSE

Due to the Basel regulation having an important impact on the financial institutions risk management, this field becomes of interest. This research aims to look into the effects the FRTB has on financial institution risk management, within market risk. The thesis will perform an evaluation of how the FRTB will affect risk management and the level as well as cyclicality in the capital charge when fully implemented.

Firstly we will look into the differences between VaR and ES when a distribution with heavier tails than the normal distribution is applied. The following section will examine the effect of the new treatment of liquidity horizon, that different market variables are subject to. Finally we will see what effect the change of risk measure and the addition of liquidity horizons will have on the capital charge.

1.4 HYPOTHESIS

Based on the empirical evidence for financial returns having fatter tails than the normal distribution, we believe that ES will be larger than VaR when using a t-distribution compared to a normal distribution. However VaR is calculated at a higher confidence level which is likely to drive the value of VaR upwards compared to ES.

Concerning the inclusion of liquidity horizons we believe that there will be different results for the three different assets. Since S&P 500 carries the same liquidity horizon in the FRTB as in the previous regulation, it is likely that there will not be any major discrepancies between the value of VaR and ES. Since the two remaining assets carry a longer liquidity horizon in the FRTB it is plausible to assume that this will cause ES to be larger than VaR.

Since there are several differences in the calculation of minimum capital requirement in the different regulations we expect the charges to vary widely in all the assets. Basel II relies on a non-stressed risk metric which possibly causes the capital requirement to be lower compared to the FRTB and Basel II.5. Since Basel II.5 includes a sVaR and a non-stressed VaR, this capital charge is likely to be high. One of the properties within the FRTB that drives the capital charge upwards is the inclusion of longer liquidity horizons. Therefore it is likely that the capital charge for the most illiquid asset will be high while the capital charge for the more liquid assets will be lower. However it is more uncertain how the fact that ES takes the average of the tail losses will affect the value of the ES-based capital charges since this is highly dependent on the sample. The same uncertainty also applies to VaR being calculated at a higher confidence level than ES.

CHAPTER 2: THE BASEL REGULATION

This section contains the background of Basel regulation and explains how the regulation has developed since it was first introduced. The regulatory framework for Basel I, Basel II, Basel II.5 and the FRTB are presented in this section.

2.1 REGULATORY FRAMEWORK

The Basel regulatory frameworks have been a part of the financial institutions since 1988 when the first Basel I regulation was established and it contained guidelines for credit risk. The main purpose of the Basel frameworks is to fortify the financial markets through the financial institutions by creating a strong regulatory foundation. This results in a higher probability for the financial institutions to absorb and handle financially stressed periods (BIS, 1988). The Basel regulatory framework is provided by the Basel Committee on Banking Supervision and is under continuous development. It provides information and understanding about issues in form of supervisory review and the overall quality within the financial institutions (BIS, 2016b). The Basel regulation that was first established in 1988 with Basel I have continuously developed into several updated versions of this framework throughout the years (BIS, 1988). In 1995 came a new publication (Basel II) that complemented the Basel I accord from 1988 adding guidelines regarding market risk (BIS, 1995; BIS 2016b).

2.1.1 THE STANDARDIZED APPROACH AND INTERNAL MODELS APPROACH IN FRTB

In the Basel framework there are two approaches for determining capital requirement for market risk, the standardized approach (from now on referred to as SA) and the internal models approach (IMA). The SA is a simple and straightforward approach used when measuring the capital requirement for a financial institution. The SA is based on three main components; the default risk, the residual risk add-on and charges under sensitivity. Since this may not be a good fit for a specific financial institution and all market risks cannot be captured by the SA, there is use of residual risk add-on to complement the market risks that may not have been sufficiently evaluated under the SA. However, the majority of international banks use the IMA (BIS, 2016b). Considering that the IMA is the most frequently applied method, this thesis will disregard from the SA.

The IMA follows the same conditional requirements as the SA, there is however a significant difference. Financial institutions that use the IMA have their own approach on how to follow the requirements. The IMA is more closely watched by the supervisory authority since these models are more complicated than the SA. The supervisory authority's incentive is to ensure that the internal models used for measuring market risk are conceptually sound and that these models are reliable when implemented. In addition to the general criteria that are also covered by the SA, internal models are subject to further requirements when estimating capital requirements. These requirements include an independent unit that values risk, regular back testing, rigorous stress-testing programs and regularly have an independent party review the risk measurement system (BIS, 2016b).

2.2 PREVIOUS REGULATION

The first Basel amendment stated that there would be a capital requirement of 8 % of the risk weighted assets, where the minimum requirement is defined as the share of risk weighted assets and not as a share of the nominal capital requirement (FI, 2013). The Risk-weighted assets were determined by the capital requirements for both market risk and operational risk and adding the sum of risk-weighted assets for credit risk as well. The market risk model was based on VaR at a 99%, one-tailed confidence interval with a minimum holding period of 10 days in Basel I and Basel II (BIS, 2005).

There have been a lot of criticism that VaR has been too reliant on normal distributions and also that all held positions were considered easy to liquidate in Basel II, that was clearly seen as insufficient and naïve after the financial crisis. This lead to Basel II.5 where regulators attempted to create a system that compensated for these specific shortcomings. In Basel II.5 the market risk framework was specifically targeted with these regulations. The element with most impact within Basel II.5 was the requirement of calculating a stressed VaR, (sVaR). The sVaR drove the risk weighted assets to a higher level and increased the capital requirements by a factor of between two to three (Armour et al, 2016). According to Mckinsey (2012) the higher capital requirement makes the financial system safer. However it can be deemed as a blunt instrument from a modeling perspective and because of this, financial institutions are in need of refined risk models. Robobank (2016) clarified that Basel II.5 concerns market risk meanwhile Basel III concerns credit risk, which is beyond the scope of this thesis. However it is notable to add that Basel III will increase capital requirements even further in credit risk, adding on the 8 % capital requirement with increased Core Equity Tier 1 capital (CET1), a counter-cyclical capital Buffer (CCCB) and capital conservation buffer (CCB).

2.2.1 QUANTITATIVE STANDARDS FOR BASEL I, II AND BASEL II.5

In 1995 an amendment to the Basel I regulation was published and aimed to revise the regulation regarding market risk. This amendment required financial institutions to calculate their capital charge using a VaR-model. With this amendment, the capital was determined as the higher of the previous days VaR or the average of the daily VaR over the preceding 60-days (eq. 1). The VaR was required to be computed at a 99 % confidence level with a minimum holding period of 10-days (BIS, 1995). According to Hull (2015) this became known as the "1996 Amendment" and the capital requirement for market risk in Basel II remained unchanged since the 1996 amendment. Considering that Basel I with the 1996 amendment and Basel II value market risk in the same manner, we will refer to both these as Basel II.

In the aftermath of the financial crisis that started in 2007, the 1996 amendment was accused of overlooking some key risks concerning market risk. During the crisis the losses in a majority of financial institutions trading books had exceeded the minimum capital requirement. As a response to this, sVAR was introduced to the regulatory capital requirement (BIS, 2011b). According to Hull (2015) the sVaR is a VaR calibrated to a 12 month period of financial stress. This change has become known as Basel II.5. An important property of Basel II.5, is according to Bank for International Settlements (2011b), to reduce pro-cyclicality of the minimum capital requirement for market risk.

For Basel II and II.5 the VaR calculation should be performed daily and a minimum holding period of 10 days should be considered. A confidence level of 99 % is to be used. However, no particular model is required to be used (BIS, 2011b; BIS, 1995).

The capital requirement for Basel I, Basel II and Basel II.5 is as follows:

Basel II

$$C_A = Max(VaR_{t-1}, m_c * VaR_{avg}) + \text{SRC} \quad (1)$$

Where SRC is a specific capital charge for idiosyncratic risk based on the specific financial institution. The m_c is a multiplying factor with a value set between 3 to 4 and relates to the ex-post performance of the IMA model within the financial institutions. Depending on the performance financial institutions may be required to "add" to the multiplying factor (BIS, 2011b). This also includes m_s (eq. 2) where m_c also is considered in Basel II.5. The VaR_{t-1} is the previous day´s VaR and the VaR_{avg} is the average of VaR the past 60 days.

Basel II.5

$$C_A = Max(VaR_{t-1}, m_c * VaR_{avg}) + Max(sVaR_{t-1}, m_s * sVaR_{avg}) \quad (2)$$

Since sVaR is likely to be equal or greater than VaR, Basel II.5 (eq. 2) is likely to cause the capital requirement to be at least doubled compared to Basel II (Hull, 2015).

In Basel II and Basel II.5 financial institutions are allowed to calculate the one day VaR and thereafter scale the one day estimate using the square root of time. This process generates a 10-day estimate for VaR.

2.3 THE FUNDAMENTAL REVIEW OF THE TRADING BOOK - FRTB

The development of a more sophisticated system has formed the latest Basel accord, the FRTB. The FRTB is a new way for financial institutions to still have a flexible way of using internal models but still maintain a minimum standard when they calculate their capital charge respectively (Armour et al, 2016).

The first and foremost new standard is ES, which is replacing VaR as the primary way of measuring risk. ES is to be computed on a daily basis for the entire internal model as a whole within the financial institution. Added to this will be the trading books and trading desks. These must also be computed daily, if they are to be included within the internal model. ES will be based on a one-tailed confidence level of 97.5 % comparable with a 99 % VaR that were the previous regulatory standard (BIS, 2016b).

2.3.1 TRADING BOOK

A trading book consists of instruments that account for the value of all assets that are being held. The instruments are broadly depicted as financial instruments, commodities and foreign exchange where financial instruments include both derivatives and cash instruments. It must be clear what procedures and policies a financial institution have when determining which instruments to include in the specific trading book. Depending on what instruments that are included or excluded from the trading book will affect the calculation of the capital required by regulations. There is also a requirement that the financial institutions must conduct ongoing evaluations of the instruments that are left out of the trading book to be able to assess if the assets should be considered within the trading book. However there are restrictions whether to move instruments between the trading book and the banking book after the initial placement of an asset. Since the trading book attracts higher market risk capital than the banking book there will be strict regulation between these due to the incentives for arbitrage between the books (BIS, 2016b). The regulatory system is established so that switching books can be allowed by the appointed supervisor, but should only be considered in extraordinary circumstances. An example of this would be when a financial institution restructures the organization. This may affect the present valuation of assets. This results in that financial institutions must hold instruments in the trading books that are subject to clear and specific policies and procedures that ensure that the financial institutions actively ensures their risk management in assets held. (BIS, 2016b).

2.3.2 Trading Desk

A trading desk is a group of traders or trading accounts. A trading desk must be equipped with a well-defined business strategy where primary activities and trading strategies are stated (BIS, 2016b). For selected desks that are permitted to use the IMA should all be included in the internal model when calculating ES. This will be the basis of the internally modelled capital charge (IMCC) where the financial institutions will have free rein from supervisory restraints when classifying the cross-class correlations (IMCC(C)), which is considered the unconstrained capital charge. IMCC(C_i) is calculated by taking the partial ES charges from the risk factors (equity risk, exchange rates- and interest rate risk) and are summed up to IMCC(C_i) that is considered the constrained capital charge. These two combined are the basis of the actual capital charge for a financial institution and the two approaches, IMCC(C) and IMCC(C_i) carry equal weight in the IMCC, that is based on the average of IMCC(C) and IMCC(C_i). The formulas for the IMCC are the following:

$$IMCC(C) = ES_{R,S} * \frac{ES_{F,C}}{ES_{R,C}} \quad (3) \qquad And \qquad IMCC(C_i) = ES_{R,S,i} * \frac{ES_{F,C,i}}{ES_{R,C,i}} \quad (4)$$

These equations for constrained and unconstrained ES values summarize into:

$$IMCC = \rho\left(IMCC(C)\right) + (1-\rho)(\textstyle\sum_{i=1}^{R} IMCC(C_i)) \quad (5)$$

Based on the assumptions and restrictions made in the thesis, $ES_{F,C}$ (all risks in the current portfolio) and $ES_{R,C}$ (reduced risks in the current portfolio) are the same, which makes the difference in IMCC(C) and IMCC(C_i) to be $ES_{R,S}$ and $ES_{R,S,i}$, which are calibrated to a stressed period. The period under stress is required to be the same when computing the different risk classes ($ES_{R,S,i}$) and the portfolio $ES_{R,S}$. Since both IMCC(C) and IMCC(C_i)

reduces to the same value the ρ will not make a difference when calculating the IMCC in the thesis. BIS (2016b) has decided that ρ shall take on the value of 0.5 in the internal model and by that put equal weights on the constrained and unconstrained model. This makes the model to consider both diversification in IMCC(C) and the non-diversified IMCC(C_i).

When IMCC(C) and IMCC(C_i) are defined, the capital requirement can then be solved for the specific financial institution. The capital charge is calculated by the maximum ES in the most recent observation and also by taking the average of the previous 60 days of ES and scaling the average by a multiplier (m_c). This multiplier is set between 1.5-2.0 and depending on the risk level within the financial institution it can be changed by supervisory authorities. Based on ex post performance the financial institution may be forced to "add" onto the multiplying effect to maintain a stable predictability. This is done by back-testing VaR with a confidence level of the 99 % where all risk factors are to be included (BIS, 2016b). In the thesis the multiplier basis of 1.5 will be used where no assumptions on held assets will be made. This is reasonable since we look at indices exchange rates isolated from other risk factors.

Each financial institution that is governed by the Basel regulation must on a daily basis meet the capital requirement according to the following formula:

$$C_A = max\{IMCC_{t-1} + SES_{t-1}; m_c * IMCC_{avg} + SES_{avg}\} \qquad (6)$$

Where $IMCC_{t-1}$ as previously stated reduces to a stressed ES and $IMCC_{avg}$ reduces to an average of the preceding 60 stressed ES. SES_{t-1} and SES_{avg} (in eq. 6) are non-modelable factors with stressed capital add-on within the trading desks that are eligible to incorporate financial instruments within the trading book. These will reduce to zero since the risk factors in the thesis are modelable factors. The thesis will therefore consider the reduced capital requirement formula:

$$C_A = max\{IMCC_{t-1}; m_c * IMCC_{avg}\} \qquad (7)$$

The total capital charge that the financial institutions must hold is based on the capital requirements from the selected trading desks that use the IMA and the other trading desks that use the standardized capital charge. Together they form the formula:

$$ACC = C_A + DRC + C_U \tag{8}$$

ACC represents the total capital requirement, C_A is the capital charge based on the trading desks that use the IMA, C_U is the capital charge for the risk factors that cannot be modeled after the IMA. Lastly DRC is the default risk charge model. (BIS, 2016b). In this thesis we will only look into a simplified IMA approach which will only include the C_A. This will give us an idea of how the FRTB will affect financial institutions risk management since we consider the factor within the model that is most risk prone and where there is most likely to be big losses.

2.3.3 QUANTITATIVE STANDARDS WITHIN THE FRTB

Financial institutions stand out in the way that they must show that capital requirements are met on a continuous basis, including forward sales and purchases. They are tested through a supervisor authority by different measures to ensure that financial institutions do not exceed their market risk capacity. This mainly concerns larger banks of which the majorities are using the IMA. Using the IMA gives financial institutions a way to maintain a strategic management system that is structured after strengths, something that the SA may not be able to apply in the same way. If a financial institution fails to meet set requirements for market risk the authority will make sure the financial institution takes immediate action to correct the offset in market risk. The capital requirements for market risk are as for operational- and credit risk consolidated on a worldwide basis. This allows financial institutions to use trading books that include just the short and long positions, independent on where the assets are booked. The trading books must be valued every day and recognize the change of value in terms of losses and profit (BIS, 2016b).

2.3.4 *LIQUIDITY HORIZON*

One of the more important regulatory differences within the FRTB is the liquidity horizons. The liquidity horizon is to be calculated based on ES that has a base liquidity horizon of 10 days which can be scaled depending on the instruments liquidity. The liquidity horizons range from 10 days, which concerns the most liquid assets such as stocks to 120 days concerning for example credit spread volatility (Appendix). It will no longer be permitted to use the square root of time when scaling the risk. The square root of time is a way to scale a one-day holding period up to a 10-day holding period, as is the prescribed horizon in Basel II (BIS, 2011b).

The ES, which includes varying liquidity horizons, will be calculated according to equation 9.

$$ES = \sqrt{(ES_T(P))^2 + \sum_{j\geq 2}^{5} ES_T(P,j)\sqrt{\frac{(LH_j - LH_{j-1})^2)}{T}}} \qquad (9)$$

Where each liquidity horizon is calculated separately meanwhile all the other assets are held constant, starting with the most liquid assets of 10-days and lastly the 120-day liquidity horizon.

Table 1 show how the assets are given different liquidity horizons, where a horizon of 10-days is given to the most liquid assets meanwhile 120-days are given to the most illiquid assets.

Table 1. Liquidity Horizons

Category	Liquidity Horizon (LH_j)
1	10
2	20
3	40
4	60
5	120

Source: BIS (2016b)

In equation 9, ES is the expected shortfall that is based on the new regulatory adjusted time horizon liquidity that is based on 10 days, T. $ES_T(P)$ is the portfolio and its positions that are concerned with shocks that can offset the risk factors. $ES_T(P, j)$ is the subset of risk factors that can shock the different positions, p_i when the other factors are held constant.

2.3.5 *STRESSED PERIOD IN FRTB*

The FRTB improves the Basel II.5 reform that addressed the shortcomings during the financial crisis when the trading books exposure was undercapitalized by using stressed periods as a measurement (BIS, 2012). ES must also be calibrated to the most stressed 12-month period based on the financial institutions current portfolio. The stressed period should include the time period in which the largest loss for the portfolio occurred. When finding the stressed period, data from 2007 and forward must be used and each observation has to be given equal weights. This is done by using a more indirect approach, where the risk factors used are reduced and must be relevant for the currently held portfolio. This reduced set of risk factors must be approved by the appointed supervisory authority and must show valid for a longer period of historical data. The reduced set of risk factors must also when compared with the full ES model be able to explain at least 75% of the fully specified ES model when measured over a 12 week period. The internal model that is to be used when calculating ES is not required to be based on a specific ES-model, as long as it follows previously stated criteria. However the financial institutions must meet the capital requirement on a daily basis (BIS, 2016b).

Instead of doubling the capital requirement, as Basel II.5 does, using a blunt instrument to solve an advanced market such as the financial market as discussed by Mckinsey (2012), the FRTB highlights the importance of liquidity in the different assets as a simple, but sophisticated instrument (BIS, 2012).

2.3.6 *SUMMARY OF THE FRTB*

The FRTB will be the new framework for financial institutions, successively implanted until 2019. Three major changes are therefore central in the FRTB. First and foremost the regulation requires financial institutions to use ES instead of VaR as a basis for the calculation. Secondly assets will be treated as having different liquidities depending on the instrument, compared to previous regulation where all assets carry the same liquidity. Lastly, the capital requirement will be based on a single risk metric calibrated to a stressed period.

CHAPTER 3: RISK ESTIMATION METHODS

This section contains a theoretical background regarding the definitions and estimation approaches of the two risk measures Expected Shortfall and Value-at-Risk that is used in the research. Information regarding how the estimation approaches are used can be found in the Methodology chapter.

3.1 VALUE-AT-RISK

Due to being perceived as a concise measure of downside risk, Value-at-Risk has become the most popular technique in risk management (Chu-Hsiung & Shan-Shan, 2006). Intuitively VaR can be defined as summarizing the worst loss over a specific time horizon for a given confidence level (Jorion, 2001). When using this measure we are interested in being able to say that we are certain, to some degree, that we will not lose more than a specific amount of money for a given time period (Hull, 2015).

According to Nilsson (2014) VaR can mathematically be defined according to equation 10.

$$VaR_{\alpha}(L) = min\{l : \Pr(L > l) \leq 1 - \alpha\} \qquad (10)$$

VaR can therefore be described as the smallest loss (l) that causes the probability of future loss in a portfolio (L) larger than l, to be less or equal to $1 - \alpha$. Where L is the stochastic variable.

For a continuous loss distribution the definition of VaR can be restated according to equation 11.

$$VaR_{\alpha}(L) = Pr\big(L > VaR_{\alpha}(L)\big) = 1 - \alpha \qquad (11)$$

Acerbi and Tasche (2001) argue that considering that VaR simply is a threshold, the measure is indifferent about the losses that can occur beyond this threshold. They further argue that because of this, portfolios with identical VaR can carry different risk. Yamai and Yoshiba (2005) state this problem in perhaps a clearer manner. They state that VaR does not regard losses beyond the VaR level and that the measure is not coherent. The lack of coherency in VaR means, according to Acerbi and Tasche (2002) that the risk of a portfolio can be larger than the sum of the individual positions risk that the portfolio consists of. Due to VaR not being sub-additive it, in some cases, punishes diversification rather than rewarding it and due to this a new risk measure advanced, namely Expected Shortfall (Harmantzis et al., 2006).

3.2 EXPECTED SHORTFALL

As an alternative to VaR, Expected Shortfall has been found to be a coherent risk measure that can dominate VaR (Tasche, 2002). After the notion of coherency had been introduced ES was brought forward. This was due to ES both being both coherent and easy to compute (Acerbi & Tasche, 2002). According to Hull (2015) ES can be defined as the expected loss during some specified time period conditional on the loss being larger than a specified percentile of the loss distribution. Considering this definition, ES can be thought of the expected loss in dire circumstances.

ES can according to Dowd (2005) formally be described as the average VaR for all confidence levels equal to or above the chosen confidence level (α). We can therefore calculate ES as the average of VaR at confidence level α to one. The mathematical definition can therefore be stated as in equation 12.

$$ES_{\alpha}(L) = \frac{1}{1-\alpha}\int_{\alpha}^{1} VaR_x(L)dx \quad (12)$$

Acerbi and Tasche (2001) argue that sub-additivity is an essential quality in a risk measure when it comes to both capital adequacies in banking supervision and in portfolio optimization. They also argue that ES is a more simple concept than VaR and that any financial institution that already computes VaR easily can switch to calculating ES.

3.3 PARAMETRIC APPROACHES

When using a parametric approach, risk is estimated by fitting probability curves to the data at hand. The risk measures that are intended to be calculated can be inferred from the fitted probability curve. This of course gives rise to problems if the density function does not form a suitable fit for the data. However parametric approaches are deemed to be more powerful than non-parametric approaches due to the additional information contained in the density function (Dowd, 2005).

3.3.1 NORMAL DISTRIBUTION

The normal distribution only needs two parameters, the mean and the standard deviation. This feature makes the normal distribution attractive when estimating VaR and ES (Dowd, 2005).

If the normal distribution is applied the VaR and ES can be calculated using the following equations.

$$VaR_\alpha = \mu + \sigma z_\alpha \tag{13}$$

$$ES_\alpha = \mu + \sigma \frac{\Phi(z_\alpha)}{1-\alpha} \tag{14}$$

Where μ and σ are the estimates for the mean and standard deviation of the losses. z_α is the standard normal variate which corresponds to the confidence level (α) that is chosen. Finally, $\Phi(z_\alpha)$ is the value of the standard normal density function for the chosen confidence level.

The estimates of VaR and ES can be stated for a certain holding period by multiplying the mean and the variance by the length of the holding period and the square root of the length of the holding period respectively. By doing this we arrive at the following formulas.

$$VaR_\alpha^h = h\mu + \sqrt{h}\sigma z_\alpha \tag{15}$$

$$ES_\alpha^h = h\mu + \sqrt{h}\sigma \frac{\Phi(z_\alpha)}{1-\alpha} \tag{16}$$

If the mean and the standard deviation are stated daily this means that we set h equal to ten if we wish to calculate the 10-day VaR and ES (Dowd, 2005).

3.3.2 T-DISTRIBUTION

Hull (2015) explains that the assumption of normality is a major drawback of the parametric approaches since market variables tend to have heavier tails than what the normal distribution accommodates. The assumption of normality therefore leads to the estimates of VaR being too low. Mabrouk and Saadi (2012) argue that the assumption of normality is unrealistic and leads to a bias in the estimate of VaR

A possible solution to accommodate the excess kurtosis is according to Dowd (2005) to use a t-distribution instead of assuming normality. The t-distribution however, has a major drawback. Since it can fail to regard constraints on maximum possible losses and as a consequence to this it might produce too high estimates. Because of this the t-distribution should be avoided when estimating risk at very high confidence levels.

When the degrees of freedom in the t-distribution become large it converges towards a normal distribution. This is reflected in the formula for VaR under a t-distribution below. As the degrees of freedom (v) becomes larger the quantile ($t_{\alpha,v}$) approaches z_α and $\sqrt{\frac{v-2}{v}}$ approaches one. Consequently the estimation of VaR under t-distribution approaches its equivalent under normality (Dowd, 2005).

According to Dowd (2005) VaR can be estimated with a t-distribution through the following equation.

$$VaR_\alpha = \mu + \sqrt{\frac{v-2}{v}}\sigma t_{\alpha,v} \tag{17}$$

Where μ and σ represents the mean and standard deviation. v the degrees of freedom and $t_{\alpha,v}$ represents the quantile.

An estimate for ES can according to Nilsson (2017) be obtained with the help of equation 18.

$$ES_\alpha = \mu + \sqrt{\frac{v-2}{v}}\sigma \frac{f^*_{std}(t_{\alpha,v})}{1-\alpha}\left(\frac{v+t^2_{\alpha,v}}{v-1}\right) \tag{18}$$

Where $f_{std}^{*}(t_{\alpha,v})$ represents the probability density function for a standardized t-distributed variable.

These estimates can be scaled for another holding period according to the following adjustments.

$$VaR_{\alpha}^{h} = h\mu + \sqrt{h}\sqrt{\frac{v-2}{v}}\sigma t_{\alpha,v} \tag{19}$$

$$ES_{\alpha}^{h} = h\mu + \sqrt{h}\sqrt{\frac{v-2}{v}}\sigma \frac{f_{std}^{*}(t_{\alpha,v})}{1-\alpha}\left(\frac{v+t_{\alpha,v}^{2}}{v-1}\right) \tag{20}$$

3.5 NON-PARAMETRIC APPROACHES

Non-parametric approaches aim to estimate the risk measures of interest without having to make any strong distributional assumptions. Instead of assuming a distribution for the losses non-parametric approaches uses the empirical distribution to estimate risk measures. This approach therefore relies on the near future being similar to the past, from which we gather our sample from. Because of this we have to decide if we believe the past data to be a good approximation of the future period which we are looking in to (Dowd, 2005).

3.5.1 BASIC HISTORICAL SIMULATION

Historical simulation is the most popular approach to calculate both VaR and ES (Hull, 2015). According to Perignon and Smith (2010) 73 % of international commercial banks such as Nordea, Wells Fargo, Rabobank and National Australia Bank, which disclose their method to calculate VaR state that they use historical simulation. Inui and Kijima (2005) further states that historical simulation is popular when determining VaR due to classical parametric methods assumption of normal distribution, which is unable to capture the fat tails in portfolio distributions.

The historical simulation uses past data on market variables to estimate what will happen in the future. By collecting data on past movements in market variables we obtain a number of different scenarios of what can happen in the next period (Hull, 2015). Dowd (2005) describes the calculation of VaR and ES through historical simulation by the following simple example. If we have 1000 days of data on losses, our VaR with a confidence level of 95 % becomes the 51st largest loss in the sample. The ES for the same confidence level is the average of the 50 largest losses.

According to Hull (2015) the one day estimates of VaR and ES can be adjusted for another time horizon by the following application.

$$VaR_{\alpha}^{h} = \sqrt{h} * VaR_{\alpha} \tag{21}$$

$$ES_{\alpha}^{h} = \sqrt{h} * ES_{\alpha} \tag{22}$$

A problem with the historical simulation, as explained by Odening and Hinrichs (2003), is due to discrete jumps in the tails of the distribution. The empirical loss distribution is smooth around the mean but since there are few extreme values in the sample, the VaR estimate becomes sensitive to changes in the data sample. Another problem that arises with historical simulation is that it becomes impossible to predict events that are worse than the largest loss in the sample at hand. Hull (2015) argues that the Historical Simulation relies on that recent history serves as a good guide of what will happen in the future. The problem however, is that this is not always the case.

Extreme Value Theory could be used to solve the problems arising from discrete jumps in the tail and not considering losses larger than in-sample losses (Odening & Hinrichs, 2003). In order to make the historical simulation to better predict the future, newer loss observations could be given a larger weight in the sample (Hull, 2015). Another possible solution is to incorporate volatility changes in the Historical Simulation, this approach is also intended to incorporate more current information in the simulation (Hull & White, 1998).

This thesis does not intend to find the best model for estimating risk. Instead the research focuses on the differences in the Basel regulation, which makes particular risk estimation models less interesting. Therefore the Basic Historical Simulation will be used.

3.4 EXPONENTIALLY WEIGHTED MOVING AVERAGE

Mabrouk and Saadi (2012) argue that financial time series shows certain stylized facts such as volatility clustering. They therefore state that any sensible risk measure should account for this. According to Hull (2015) the exponentially weighted moving average (EWMA) approach is desirable since it only requires us to store a rather small amount of data. We only need the current estimate of the variance and the most recent value of the market variable that we are studying. The weighting scheme in the EWMA process leads to the following formula.

$$\sigma_t^2 = (1 - \lambda)u_{t-1}^2 + \lambda\sigma_{t-1}^2 \qquad (23)$$

u_t represent the returns that are weighted with $(1 - \lambda)$. The risk management group RiskMetrics database sets λ equal to 0.94 for daily data in the model (Maboruk & Saadi, 2012). Through the process in the equation above we can follow changes in volatility (Hull, 2015).

According to Dowd (2005) volatility clustering should be accounted for when using a parametric model. Therefore σ_t^2 will be used in equations 13-20.

CHAPTER 4: DATA AND METHODOLOGY

This chapter will describe the methodology applied in the thesis to make the process used more comprehensible and transparent. There are obvious limitations in the approach and assumptions used in the thesis. These are made clear as to why the specific approach used is the best regarding the purpose of the thesis. Lastly three different steps are performed in order to be methodically accurate and avoid biased results.

4.1 ASSUMPTIONS AND LIMITATIONS

Since the research studies one asset at the time, the full set of risk factors will equal the reduced set of risk factors. This leads to the ratio between the full and reduced set of risk factors being equal to one (eq. 3 and 4). According to Bank for international settlement this assumption will not significantly distort the analysis (BIS, 2014).

The research uses three different indices as background for the research. These will be assumed to be sufficiently representative for their respective asset classes in order to make this research valuable. In this study the indices will represent three different portfolios that lay the foundation for the performed research. If data on financial institutions trading portfolios was available this would have made a valuable contribution to this research. Considering this, it is of importance to regard the arbitrariness of the chosen data when evaluating the results.

4.2 DATASET

This research will use three different indices in order to perform the proposed tests. In the first part of the research, in which the effect of fatter tails in financial returns is evaluated, the large cap stock index S&P 500 is utilized. In the second and the third part of the research two additional indices are included. These are the small cap index S&P 600 and S&P 500 High Yield Corporate Bond index.

All data is retrieved through Datastream (Table 2) and roughly 3000 observations are obtained for each index. Since Datastream does not automatically account for non-trading days, these have been removed manually from the data in order to only include trading days. The time period spans between the beginning of 2005 and the end of 2016 for the first part of the research. In the second and third part of the research, the same timeframe will be studied. However, the capital charge will only be calculated between 2009 and 2016. This is since the stressed period was found to occur between the end of 2007 and 2008.

Table 2. Thomson Reuters Datastream

Equity Indices	Code
S&P 500 Large Cap	S&PCOMP
S&P 600 Small Cap	SP06SVA
S&P 500 High Yield Bond Index	SP5HYBI

In order to calculate VaR and ES the return has been calculated. The research will utilize the one day return (eq. 24) as well as the 10-day overlapping return (eq. 26). Both returns are thereafter transformed to losses according to equations 25 and 27.

$$r_t = \frac{p_t - p_{t-1}}{p_{t-1}} * 100 \tag{24}$$

$$l_t = -r_t \tag{25}$$

$$r_t^{10} = \frac{p_t - p_{t-10}}{p_{t-10}} * 100 \tag{26}$$

$$l_t^{10} = -r_t^{10} \tag{27}$$

Table 3 displays the descriptive statistics of S&P 500 for the daily loss data. Most notable is perhaps that the data exhibits a skewness and kurtosis. For a normal distribution the mean and standard deviation can according to Dowd (2005), amount to any values, which exception of the necessity of a positive standard deviation. However it has the skewness is 0 and the kurtosis should be equal to 3. As seen in the table the kurtosis amounts to 11.45 and the distribution have a positive skewness. This therefore implies that the losses inhibit a distribution with fat tails.

Table 3. Descriptive statistics daily losses S&P 500

	S&P 500
Mean	-0.0279
Standard deviation	1.2313
Min	-11.5800
Max	9.0350
Skewness	0.0921
Kurtosis	11.4553

As can be seen in Diagram 1, which displays the daily losses of S&P 500 between 2005 and 2016, there is one period of distinctively high losses. This is the period between the middle of 2008 and the beginning of 2009. Since there are periods of low volatility followed by periods of higher volatility the index also seem to exhibit volatility clustering. This effect will be accounted for when comparing VaR and ES using parametric estimation approaches but not when applying a historical simulation.

Diagram 1. **Daily losses**

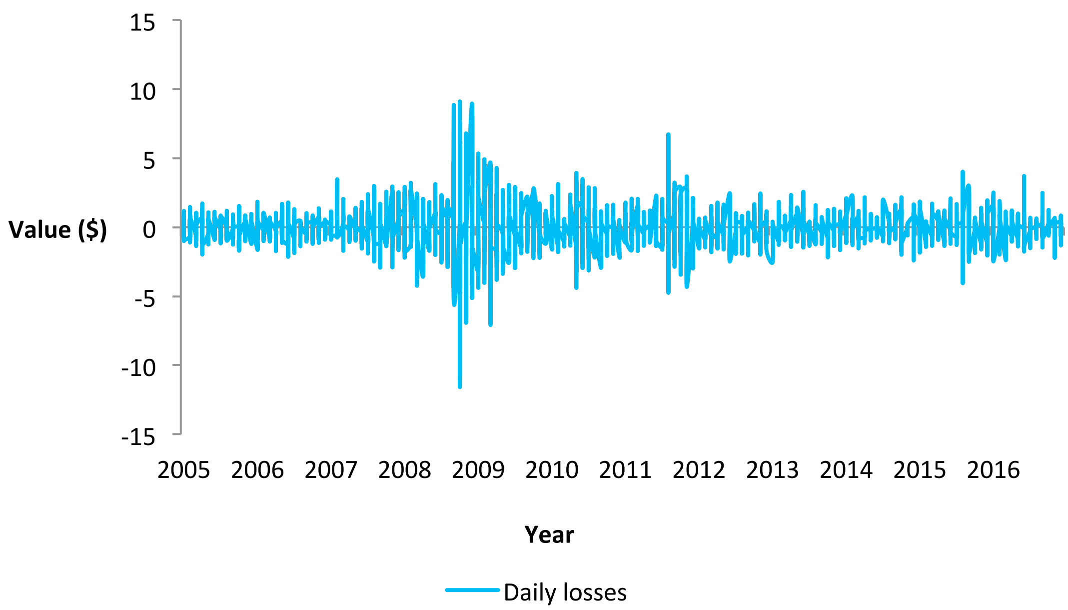


Table 4 displays the descriptive statistics for the 10-day overlapping losses. The kurtosis is noticeably high for the S&P 500 HY Corporate Bond Index, while lower for the two remaining indices. In addition to this all indices have a positive skewness. This implies that all three indices have fat tails, which is in accordance with the empirical evidence regarding financial returns. The largest losses (Max) in all three samples gives an idea of how high the estimates of VaR and ES will be since this data will be used in a historical simulation. In addition to this the standard deviation is considerably lower for S&P 500 HY Corporate Bond Index. However, the standard deviation can be an inadequate measure when dealing with non-normal distributions according to Dowd (2005). Therefore we will not draw any conclusions from the varying standard distributions.

Table 4. Descriptive statistics 10-day losses

	S&P 500	S&P 600	S&P 500 HY Bond Index
Mean	-0.2397	-0.3287	-0.0475
Standard deviation	3.0724	3.9958	1.4417
Min	-16.3798	-20.0292	-10.8757
Max	24.9866	27.8918	15.2219
Skewness	1.0815	0.7056	1.5950
Kurtosis	6.8694	4.4547	23.9704

Diagrams 2, 3 and 4 depict the 10 day losses for the three indices. The same pattern as with the daily losses can be noted here as well. S&P 500 and S&P 600 show signs of higher volatility, which also can be seen in the standard deviation in table 4. These two indices have experienced large losses in the period between the end of 2011 and the beginning of 2012.

Diagram 2. **S&P 500 - losses**

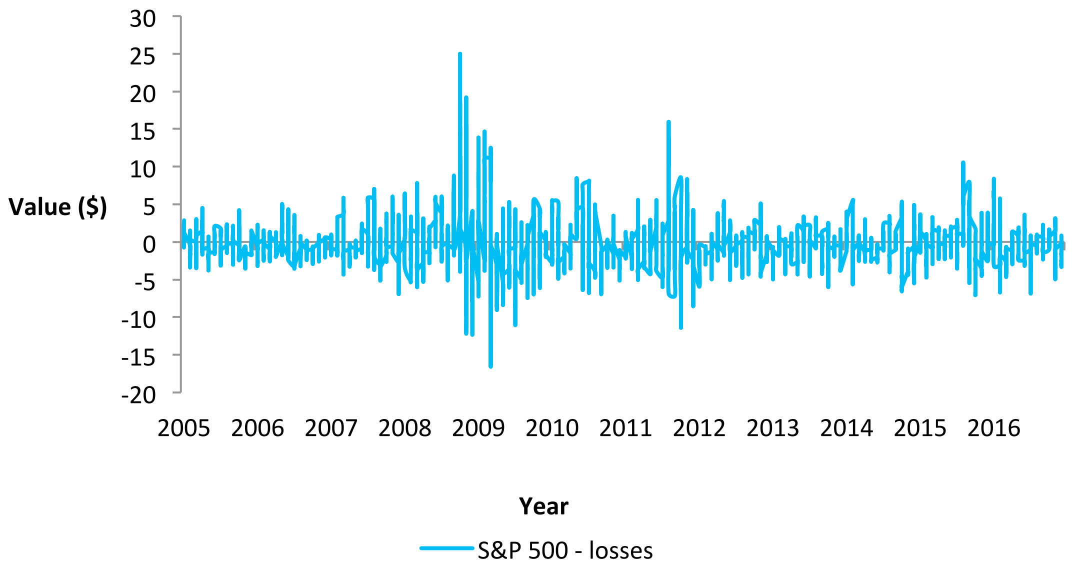


Diagram 3. **S&P 500 HY Bond - losses**

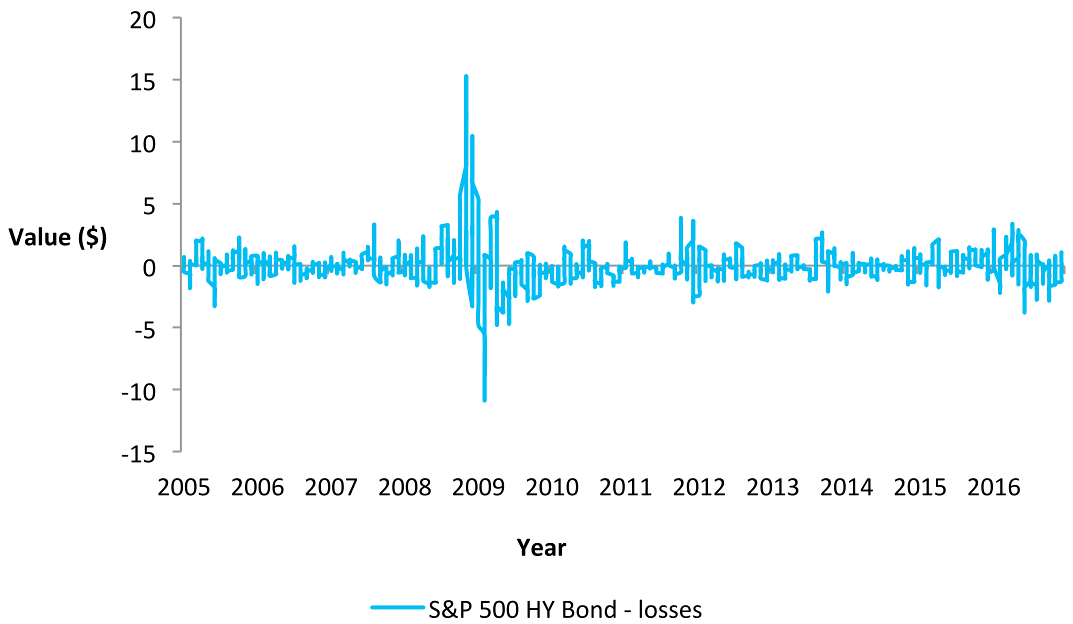
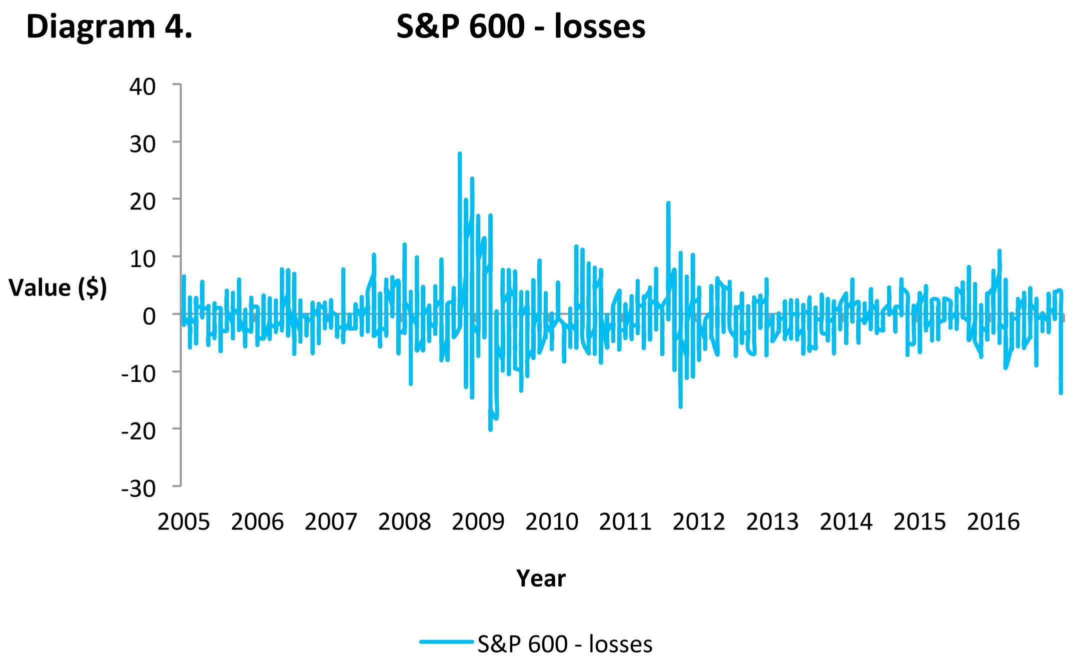


Diagram 4.



4.3 PERFORMED RESEARCH

4.3.1 THE CHANGE OF VAR TO ES

This part of the research aims to evaluate how VaR and ES can vary if a distribution with heavier tails is applied. Since Dowd (2005), Hull (2015) and Fama (1965) argues that financial data often have heavier tails than what the normal distribution has, it is reasonable to test this in order to see the effect heavier tails has on the estimation of the two risk measures. In order to study the effect of heavy tails VaR and ES are first calculated using a parametric estimation with normal distribution and thereafter a t-distribution is applied to the calculations.

VaR is calculated at a 99% confidence level and ES at a 97.5% confidence level on the S&P 500 index. Both VaR and ES are calculated using the one-day losses and the sample mean included in the observations uses loss data over the previous year (252 days). Since the Basel regulation requires financial institutions to calculate the 10-day VaR and ES, each estimate is scaled by the square root of 10 (see eq. 15, 16, 19 and 20).

In order to capture market conditions the standard deviation, obtained through an EWMA process, is included in the estimation. This means that we use the forecasted daily volatility in our estimations of the risk measures. This test stems from what Hull (2015) proposes, that VaR and ES will be almost exactly equivalent under at normal distribution when these confidence levels are applied but can vary greatly when fatter tails applied.

In the EWMA process we have set u_t equal to $l_t - \mu_{yearly}$, where μ_{yearly} is the yearly mean of the losses. When estimating VaR and ES under the t-distribution, the first 13 observations showed negative degrees of freedom. Because of this, these observations are approximated with the values obtained using the normal distribution.

4.3.2 *EFFECT OF LIQUIDITY HORIZONS*

The second part of the research aims to study the effect of how the new way of treating liquidity in the FRTB affects the difference between VaR and ES. In order to do this a non-parametric estimation of both VaR and ES is performed. The reason for leaving the parametric approach behind is due to Perignon and Smith (2010) arguing that the majority of (commercial) banks worldwide state that they use historical simulation in their estimation of VaR.

In order to test the new way of treating liquidity all three indices will be evaluated. For each index both VaR and Expected Shortfall is calculated. In the FRTB we no longer apply the square root of time since it will no longer be permitted in the framework. S&P 500 contains large cap equity and therefore has a liquidity horizon of 10-days which is the same as all assets carry in previous regulation. The two remaining indices carry a longer liquidity horizon in FRTB. S&P 600 contains small cap equity and therefore has a liquidity horizon of 20-days and S&P High Yield Corporate Bond index carries a liquidity horizon of 60-days in the FRTB. To incorporate the varying liquidity horizons equation 9 is used. The different assets used, containing different liquidity horizons are deliberately chosen to see the effect of the FRTB.

VaR is calculated by all losses over the 99% and ES is calculated as the average of the 2.5% largest losses in the sample. In order to be consistent with Basel regulation and calculate the 10-day VaR and ES the 10-day overlapping return is used which is then transformed to losses (eq. 26 and 27).

4.3.3 *CAPITAL CHARGE*

The third and last part of the research is based on the calculations performed in the second part. Calculations of VaR and ES using the market risk capital charge under Basel II, Basel II.5 and the FRTB are performed (see eq. 1, 2 and 7).

Since the calculation of capital charge for both Basel II.5 and the FRTB is calibrated to a stressed period this period is identified for each index. This is done by finding the largest loss that has occurred between to 2007 and today, which is in accordance with the quantitative standards in the FRTB. After this loss is identified a VaR and ES estimation, which includes this loss is calculated. This specific estimation is referred to as the stressed

VaR and stressed ES. In this research the period between the end of 2007 and the end of 2008 is found to be the most stressed for all assets.

Finally, the capital charge under the three different regulations is calculated separately for the three different indices. The multipliers (m_s and m_c) will be set to a minimum in each calculation of capital charge. This means that the multiplier is set equal to 3 in the calculation for Basel II and Basel II.5. The minimum in the FRTB is 1.5 that consequently is used in this research as well. The non-modelable factor, SES will not be considered since there are none present in the sample and since there are uncertainties of how to use this factor. Lastly, since we are only studying one asset at the time the reduced set of risk factors equals the full set of risk factors the IMMC will be equal to ES, calibrated to a stressed period.

The FRTB capital charge is then compared with the capital charge from Basel II and II.5 to see if there are any differences between these risk measurements. As previously stated, Basel II is based solely on VaR meanwhile Basel II.5 use stressed periods and sVaR to manage capital requirement.

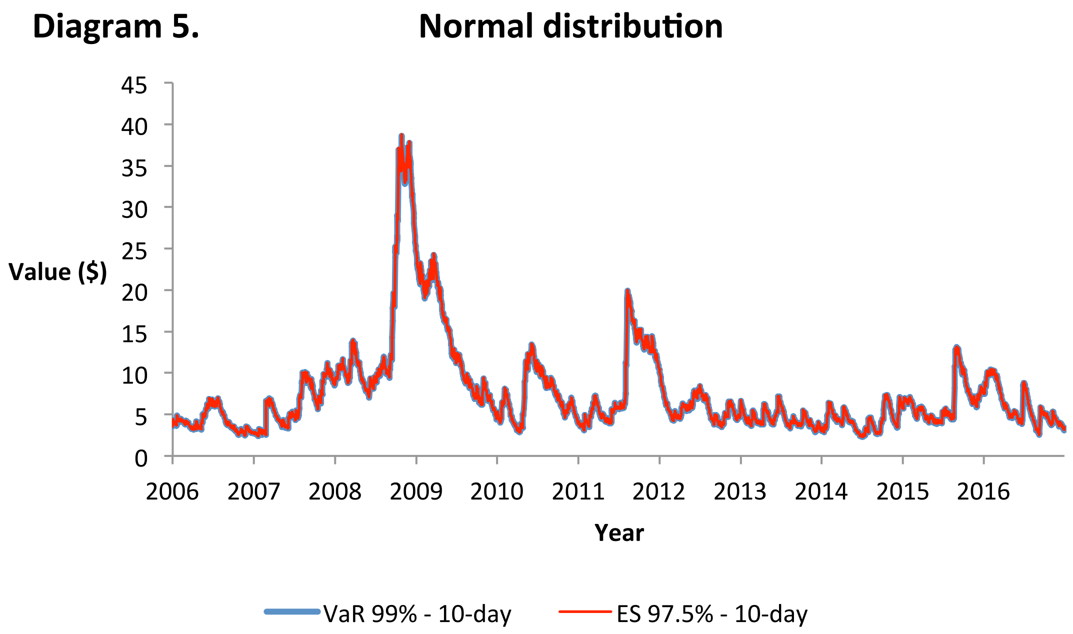
CHAPTER 5: RESULTS AND ANALYSIS

The results are presented in the following order, firstly the change from VaR to ES with presence of fat tails is evaluated. Thereafter the results of the different liquidity horizons that are displaying differences between the different assets and horizons. Lastly the capital requirements under Basel II, Basel II.5 and the FRTB for the three assets with varying liquidity horizons are analyzed. These three tests are thereafter concluded and the findings are highlighted. Lastly future research within the area is suggested.

5.1 THE CHANGE OF VAR TO ES

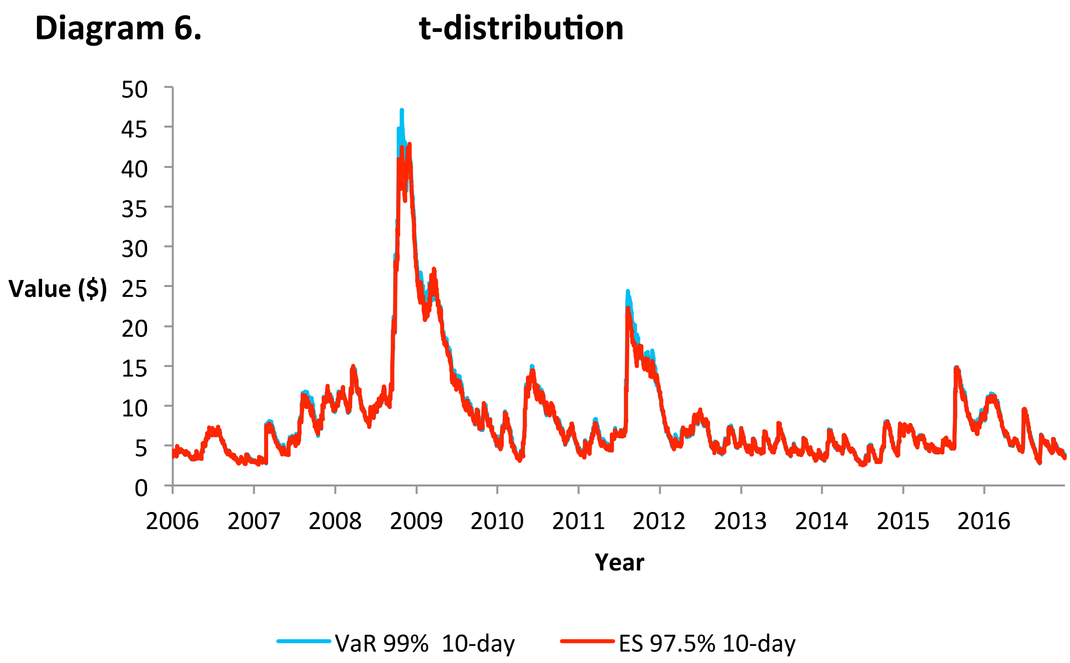
The first test describes how the different distributions are behaving when calculated for VaR and ES respectively within the different distributions. The calculations are based on the S&P 500 large cap index.

Diagram 5.



When VaR and ES are calculated using a normal distribution they amount to approximately the exact same values as seen in Diagram 5. This result corresponds to our hypothesis regarding the equality between VaR at a 99 % confidence level and ES at a 97.5 % confidence level under a normal distribution. Note however that this result is expected due to the different confidence levels forcing the estimates to be close to equal. The main concern in this test lies in the difference between the measures when the t-distribution is applied.

As can be seen in Diagram 5 there is quite a lot of variability in both measures during the studied time period. The period with the highest VaR and ES is in 2009. Since the estimations for this period is based on the previous 252 days the high value stems from a period of the financial crisis. Considering that this period is likely to have experienced large losses and high volatility it is reasonable that both the ES and VaR estimates are high. Since we have included an EWMA model in the calculations the effect of volatility clustering is accounted for.



Hull (2015) argues that ES can be considerably larger since fatter tails than the normal is applied, which also was our hypothesis. As can be seen in Diagram 6 there are some difference between the two risk measures, but only to a small extent. This result shows that the presence of fat tails in the variable does not seem to cause any major differences in the risk measures for this specific index. Note however that the VaR estimate is higher than ES during some days, which contradicts the intuition from Hull.

The reason for the small amount of difference between VaR and ES can be due to the different confidence levels used. When the same confidence level is used for both measures ES is always larger than VaR. If the most extreme losses, or the losses beyond VaR, are not considerably high this can cause ES to become lower than VaR.

5.2 EFFECT OF LIQUIDITY HORIZONS

The second test describes how different liquidity horizons affect the values of ES compared to VaR which applies to a 10-day holding period. The FRTB uses ES which incorporates varying liquidity horizons, ranging from 10-days up to 120-days. The liquidity horizons are sorted into five different asset classes, where the liquidity horizons used in the thesis are 10-days, 20-days and 60-day liquidity horizons (see Appendix).

When evaluating ES with different liquidity horizons there will be three diagrams, starting with the most liquid asset, the S&P 500 large cap index with a liquidity horizon of 10 days. Thereafter the S&P 600 small cap index, which carries a 20 day liquidity horizon will follow and lastly the S&P 500 high yield bond index with 60-day liquidity horizon is presented. All VaR calculations are made with a 99 % confidence and all ES calculations are made with a 97.5% confidence level, in accordance with regulation.

Diagram 7.

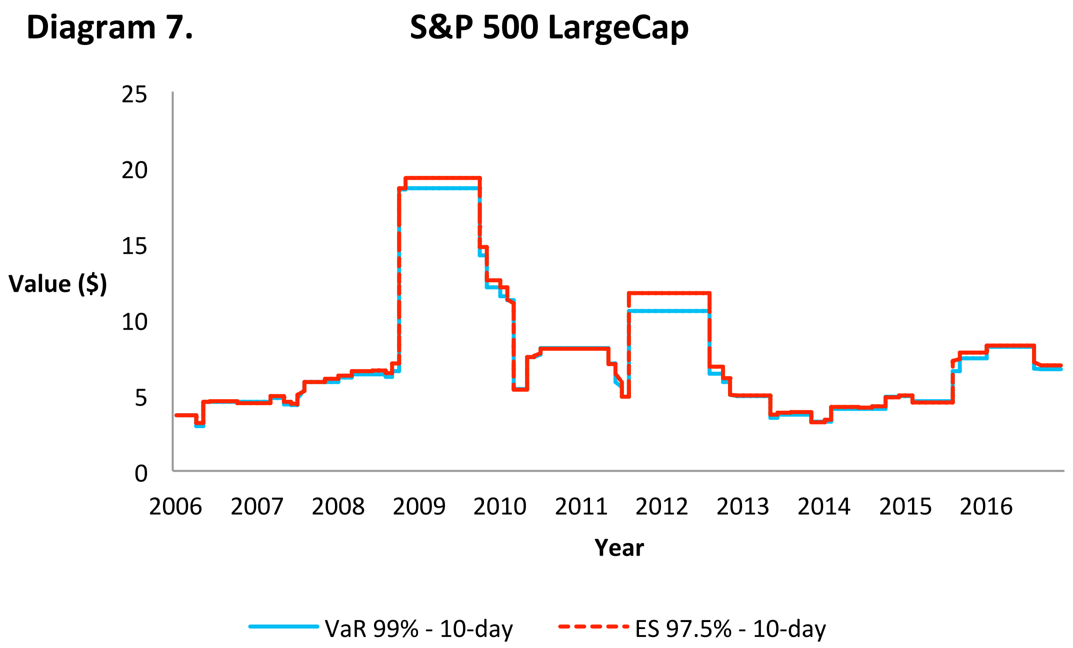


Diagram 7 is providing information about the S&P500 large cap index that carries no liquidity horizon-punishment since it is in the category that is deemed most liquid with a 10-day liquidity horizon.

No apparent pervading difference between VaR and ES can be seen for this asset. Both VaR and ES uses a 10 day liquidity horizon and therefore the differences seen in the diagram are most likely to come from the differences in the measures themselves. There are however, two periods where there are clear differences between ES and VaR. During the periods 2009-2010 and 2012-2013 ES distinctly exceeds VaR.

Since ES considers the whole right tail of the distribution while VaR merely considers a quantile point there will be differences, especially if losses in the right tail are considerably high. Therefore the differences between the risk measures are most likely to stem from large losses, i.e. considerable extreme values during the estimation periods for the two measures.

Diagram 8.

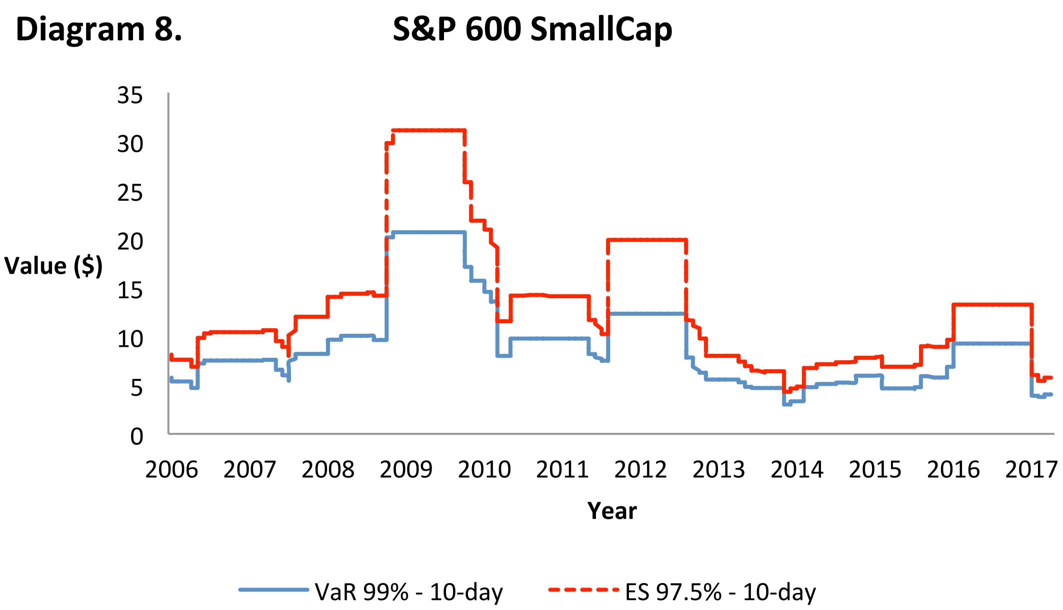


Diagram 8 provides information about the S&P 600 small cap that compared to the S&P 500 large cap carries punishment since the liquidity horizon is now extended to 20-days in the FRTB. Consequently it is deemed as less liquid than the category addressed with 10-day liquidity horizon. Similarities exist with Diagram 7 where the two most distinguishable periods are the same as in Diagram 8.

Compared to S&P 500 there is an apparent shift in VaR and ES, where ES has a higher value than VaR through the whole period. The FRTB framework consider specific risks in terms of liquidity in assets meanwhile VaR assumes the same liquidity for all instruments, which results in ES to be higher for a more illiquid asset. This highlights the important impact of liquidity horizons.

Diagram 9.

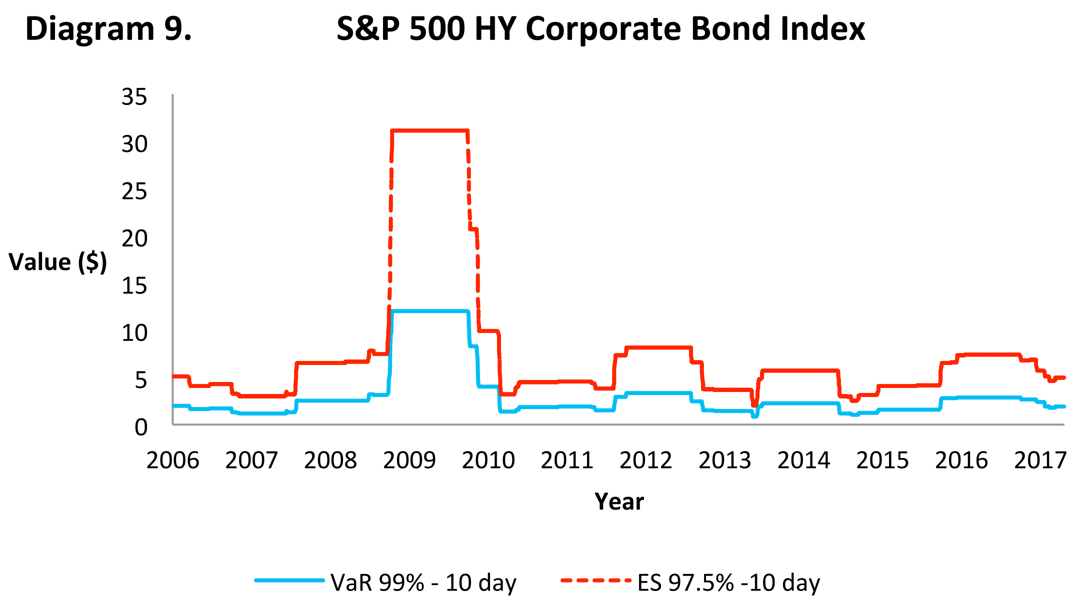


Diagram 9 is providing information about the S&P 500 high yield corporate bond index. The bond represents the highest liquidity horizon in the thesis with a liquidity horizon of 60-days and therefore also carries the largest punishment.

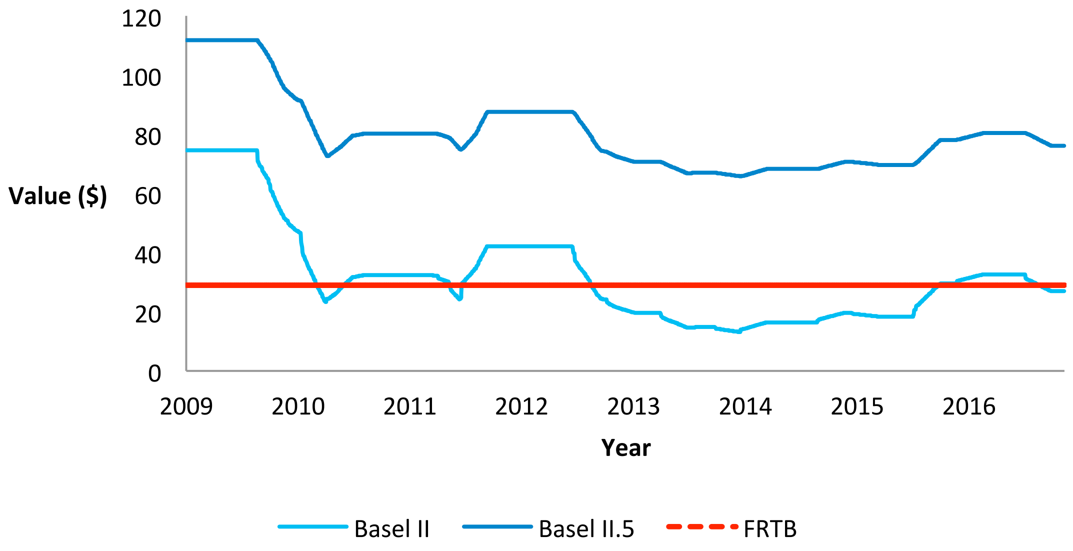
As in the case with S&P 600, this even more illiquid asset has generated a clear difference between VaR and ES. The value of ES is higher than VaR through the whole period. This gives further evidence for the FRTB treating more illiquid assets as considerably more risky.

There has been a rise in the distance between VaR and ES when comparing Diagrams, 7, 8 and 9. Even though VaR has a higher confidence level compared to ES, ES shows considerably higher values for the two more illiquid assets. Since there is no major difference between the VaR and ES for the S&P 500 index, it is most likely that the difference in the two remaining assets stems from the higher liquidity horizon.

5.3 CAPITAL CHARGE

This last section compares the different assets minimum capital requirements for market risk. For each asset the minimum capital requirement is calculated under Basel II, Basel II.5 and the FRTB. In accordance with the regulation, VaR is always calculated at a 99 % confidence level while ES is calculated at a 97.5 % confidence level.

Diagram 10. S&P 500 LargeCap - Capital Charge



In Diagram 10 we see that for the large cap equity index S&P 500 the capital charge under Basel II.5 is invariably the highest while the capital charges for the FRTB and Basel II regulation lies closer to each other and at a constantly lower level. This result corresponds back to Bank for international Settlements (2014) expectations regarding moving to a single risk measure calculated at a lower confidence level. This property of the FRTB was thought to cause the capital requirement to decrease. Since Basel II.5 relies on both VaR and Stressed VaR it is reasonable that the capital charge is high. Specifically since S&P 500 holds the shortest liquidity horizon of the studied assets. One of the major forces behind driving the capital charge upwards is absent since the liquidity horizon is 10-days and there is no punishment.

Another result that is apparent is that the capital charges under both Basel II and Basel II.5 shows signs of being pro-cyclical while the capital charge under the FRTB is constant over the whole period. This feature provides evidence for the FRTB to be successful in being less pro-cyclical, which was stated as a desirable trait. This makes the FRTB more predictable and the other models less so. However even though the FRTB proves to move towards a more sophisticated framework, considering and sorting different risk levels that corresponds with different liquidity horizons there are concerns of the complexity of implementing this framework. An important factor to address is the non-modelable assets that are still a big part of the FRTB estimations, which are not accounted for in this thesis. This follows with the BCBS´s study with the hypothetical portfolio exercise where they found it difficult to incorporate non-modelable assets as well. How this could affect the model would be speculative assumptions and is not something that would contribute in the thesis. The only thing we can state is that the non-modelable assets will have an effect on the model as a whole.

Diagram 11.

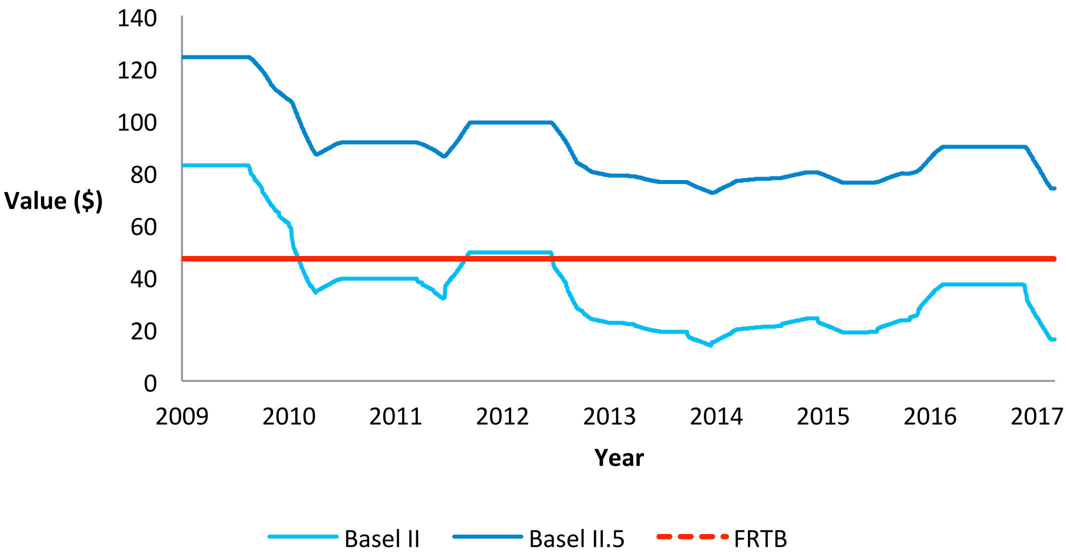
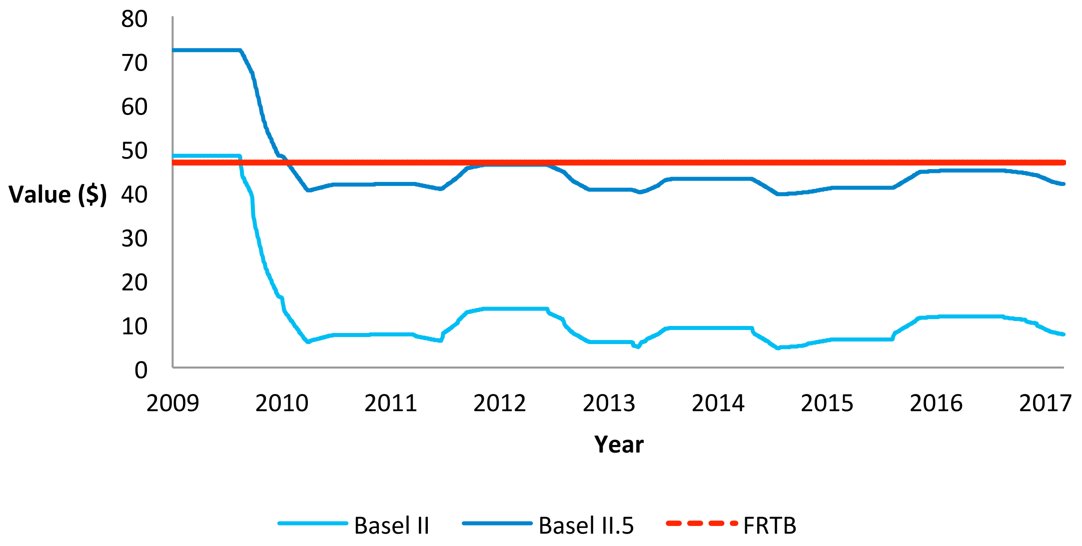


Diagram 11 based on S&P 600 small cap index show that when looking at an asset with a longer liquidity horizon the capital charge under the FRTB is driven upwards. This illustrates that the inclusion of liquidity horizons seemingly have an important effect on the capital charge.

The same appearance regarding the cyclicality as with S&P 500 can be seen for this asset. The capital charge under the FRTB is constant through time while the VaR based capital charges show some cyclicality. The effect of the double capital charge in Basel II.5 (see eq. 2) is clearly visible.

Diagram 12. Corporate High Yield Bond Index - Capital Charge



The different capital charges for S&P HY Corporate Bond Index are quite different compared to the two other assets (Diagram 12). Here the capital charge under the FRTB is the highest during the majority of the studied time period. Since S&P High Yield Bond Index carries the longest liquidity horizon this result correspond to the expectation in Bank for international Settlements (2014) where the inclusion of different liquidity horizons was thought to drive the capital charges upwards.

We note however that during the initial period the capital charges under Basel II and II.5 are both higher than the requirement in the FRTB. Since the initial capital requirement stems from a period of significant stress it is hardly surprising that the values are high. It is also important to note that the requirement under the FRTB constantly, through the whole time period, is calibrated to this specific stressed period.

The longer the liquidity horizons are, the more effect of the FRTB framework is shown in form of capital requirements as seen in diagrams 10, 11 and 12. One could argue that the capital requirement in the FRTB is too high in diagram 12, when compared with Basel II and II.5. Though considering that less liquid assets put on a lot more risk it might be reasonable to find the FRTB to be as high as it is for a liquidity horizon of 60-days. The FRTB add the concern for the assets liquidity meanwhile Basel II and II.5 do not account for the difference in liquidity among assets. Since the capital charge for both S&P 500 and S&P 600 that contains assets in form of equity is lower than Basel II.5. This corresponds to the study from BIS (2014) that also proved equity to be subject to lower capital charge.

As we see in the diagrams 10, 11 and 12 the capital charge under the FRTB capital charge show no signs of cyclicality. Since the capital requirement in the FRTB relies on a single risk metric calibrated to a stressed period this result is reasonable. A change in capital requirement under the new proposed regulation is in fact driven by entering a new stressed period, which in turn later causes a change in the capital requirement. With regards to this the FRTB shows signs of being successful in being less pro-cyclical.

One thing that is noticeable is that Basel II and Basel II.5 are based on the same calculations (eq 1 and 2). The difference is that Basel II.5 is enhanced by a constant in form of sVaR. Comparing diagram 10, 11 and 12 we see that Basel II.5 takes on a high value in liquid assets meanwhile in more illiquid assets takes on a lower value when compared with the FRTB. The FRTB has the reverse effect of a lower value in liquid assets and a higher value in illiquid assets (Diagram 10, 11 and 12).

This shows that Basel II.5 assigns a high capital charge independent of liquidity in the assets considered. Meaning it assigns high capital charge even though the assets can be liquidated easily compared to the FRTB which considers the liquidity in assets, assigning lower capital charge to a more liquid asset.

CHAPTER 6: SUMMARY AND CONCLUSION

The research cannot prove any major differences between VaR and ES when fat tails are present. Since VaR in some cases was shown to exceed ES under a t-distribution it does not correspond to our hypothesis.

When looking into the difference in how to treat liquidity in the FRTB and previous regulation, the research show evidence of discrepancies between the regulations. The new amendment incorporated in the FRTB that forces financial institutions to treat assets as having different liquidities causes the ES to be higher compared to VaR for more illiquid assets. This result corresponds to our hypothesis.

Considering the capital charges in the FRTB was low for the more liquid assets and high for the illiquid assets the inclusion of the liquidity horizon in the FRTB show signs of being an important factor in the new regulation. The main argument for the capital requirement under the FRTB to often be lower than the current regulations requirement is moving to a single risk metric rather than two. Another plausible explanation is the use of a lower confidence level. As proven by the discrepancies between the capital charge in the different assets it seems as the new way of treating liquidity in assets is the main force behind causing an increase in the capital charge in the new proposed regulation. This result corresponds to our hypothesis regarding higher capital charge for more illiquid assets.

The research indicates that the increased liquidity horizons incorporated in the FRTB is likely to have a major impact for financial institutions. This is clearly illustrated when the diagrams for S&P 500, S&P 600 and S&P 500 HY Corporate bond Index are compared.

When evaluating these results it is of importance to regard the used set of data. It is perhaps most important to note that this research has included three of five possible liquidity horizons. The two liquidity horizons that have been left out are 40 and 120-days. It has been shown that a longer liquidity horizon causes the capital charge to increase. These two, relatively long, liquidity horizons are therefore also likely to cause an increase in the minimum capital requirement compared to previous regulation.

Considering that the research has left out the liquidity horizons of 120 and 40-days we cannot conclude the same result as BIS (2015). However the research in the thesis has found evidence that longer liquidity horizons drive the capital charge upwards. Therefore an inclusion of the two excluded horizons is plausible to generate the same result as BIS (2015).

A cause for concern when implementing the FRTB is the pro-cyclicality of previous regulation. This was something discussed in Basel II.5 as well. The research found the FRTB capital requirement to be constant through time while the other two capital requirements showed signs of being more pro-cyclical.

To summarize, this research has found some important factors in the FRTB that will affect minimum capital requirements for market risk within the financial institutions. Most notable was the new way of treating liquidity in assets. However there are some factors that were not included in the thesis that can have an important impact in the form of non-modelable assets. We conclude that we have found results that indicate important impacts of the FRTB but cannot conclude that these will be valid in a fully operated model.

SUGGESTED RESEARCH

This study could be replicated for another dataset. If access to a financial institutions trading desk was accepted there would be a larger variety of instruments that could be included. This would result in a broader and more general result. However this type of research might prove to be hard since, as previously stated, even banks were unable to fully include non-modelable risk factors in the calculation.

More illiquid assets will be subject to a higher Expected Shortfall compared to Value-at-Risk because of the inclusion of longer liquidity horizons in the FRTB. This might cause financial institutions reluctant towards including illiquid assets in their trading books and this in turn, could generate a reallocation of illiquid assets in the financial sector. Due to this possible outcome, the allocation of assets after the implementation of the FRTB becomes an interesting field to study. There are growing concerns for how the financial institutions will cope with the increase in the minimum capital requirements within illiquid assets where the two foremost concerns are shadowbanking and how the financial institutions will be able to keep the revenue streams. These would be interesting areas to explore when the FRTB is fully implemented.

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APPENDIX

Risk factor category	N	Risk factor category	N
Interest rate	10	Equity price (small cap): volatility	60
Interest rate: unspecified currencies	20	Equity: other types	60
Interest rate: volatility	60	FX rate: specified currency pairs	10
Interest rate: other types	60	FX rate: currency pairs	20
Credit spread: sovereign (IG)	20	FX: volatility	40
Credit spread: sovereign (HY)	40	FX: other types	40
Credit spread: corporate (HY)	40	Energy and carbon emissions trading price	20
Credit spread: corporate (HY)	60	Precious metals and non-ferrous metals price	20
Credit spread: volatility	120	Other commodities price	60
Credit spread: other types	120	Energy and carbon emissions trading price: volatility	60
Equity price (large cap)	10	Precious metals and non-ferrous metals price: volatility	60
Equity price (small cap)	20	Other commodities price: volatility	120
Equity price (large cap): volatility	20	Commodity: other types	120

Source: Basel, Minimum capital requirements for market risk (2016b)