Understanding some new Basel III implementation issues for Lebanese Commercial Banks

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Abstract

This thesis aims at providing Bank Audi with an updated tool to understand and investigate in given risk types encountered in their portfolios and the way Basel suggests computing their capital charges. International regulator is constantly changing and modifying previously used approaches to enhance the reflection of the market and banking sector risks. The recent financial crisis played a major role in these reforms, in addition the situation of Bank Audi and the markets it is operating in, represent certain specifications that should be accounted for. The work handles interest rate risk in the trading book, Counterparty Credit Risk faced with derivatives along a closer look on the Credit Valuation Adjustment topic and the incorporation of Wrong Way Risk.

The first part discusses the new Fundamental Review of the Trading Book: focusing on the general interest rate risk factor, the paper compared Basel's Sensitivity Based Approach (SBA) capital charge to more traditional approaches of VaR using several models such as Generalized Auto Regressive Conditional Heteroscedasticity (GARCH), Principal Components Analysis (PCA), Independent Components Analysis (ICA) and Dynamic Nelson Siegel. Application on portfolios with zero coupon bonds of different sovereigns revealed the divergence in results between stable markets (such as France and Germany), less stable (such as the USA) and emergent markets (such as Turkey).

The second part is dedicated to the Counterparty Credit Risk. A new capital charge methodology was proposed by Basel and set as a standard rule in 2014: the Standardized Approach for Counterparty Credit Risk (SA-CCR). Applying this approach on different derivatives portfolios, we compared it to internal models. The internal methodologies incorporated historical estimations and future projections based on Vasicek and GARCH models. Different hedging cases were investigated on EUR and USD portfolios. The impact of each hedging technique and the difference between IMM and the standardized methods were highlighted in this work: without hedging, the internal approach amends 80% of the standardized capital whereas, in general, the hedging is encouraged more under the standardized approach relatively to its capital reduction under the internal model.

The third part remains a part of the Counterparty Credit Risk however, the main focus in this work is the Credit Valuation Adjustment. This topic was neglected in terms of capital charge earlier but due to its important impact is now incorporated as a capital charge amended when no central clearing is put in place when dealing with derivatives. We focus on the regulatory approaches of capital computation, comparing both accepted approaches based on portfolios of interest rate swaps held with investment grade sovereigns. An incorporation of the Wrong Way Risk is another addition in this work: using Error Correction Models we were able to reflect the impact of the correlation between the exposure and the credit quality of the investment grade sovereign we are dealing with. Based on such results, a suggestion of a re-calibrated standardized approach is in place to encourage the use of the CDS as an indicator of the credit quality of the counterparty and not its grade (investment or not) as followed by the new Basel regulations.

Keywords: Basel III, Interest Rate Risk, Counterparty Credit Risk, Credit Valuation Adjustment, Wrong Way Risk.

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Résumé

L'objectif de cette thèse est de fournir à la banque Audi un outil à jour sur les façons de calculer le capital requis par Bâle pour certains risques financiers présents dans le portefeuille de la banque. La régulation internationale est en développement continu : des nouvelles approches sont proposées afin de couvrir au mieux les risques du marché et du secteur bancaire. Les crises financières récentes étaient à la base de ces réformes. De plus, la Banque Audi opère sur des marchés qui présentent des caractères spécifiques qu'il faut prendre en considération lors du calcul du capital requis. Cette thèse se concentre sur le risque de taux d'intérêt dans le livre de négociation de la banque, le risque de contrepartie et précisément l'ajustement d'évaluation de crédit tout en incorporant l'impact de la corrélation entre la qualité du crédit de la contrepartie et l'exposition prévue envers cette même contrepartie.

La première partie de cette thèse traite de la nouvelle méthodologie suggérée par Bâle sur le Trading Book : Fundamental Review of the Trading Book. Le risque de taux d'intérêt est particulièrement analysé en utilisant la méthode standard, Sensitivity Based Approach (SBA), et des méthodes plus 'traditionnelles' de valeur à risque tout en utilisant différents modèles tels que Generalized Auto Regressive Conditional Heteroscedasticity (GARCH), l'Analyse en Composantes Principales (ACP), l'Analyse en composantes indépendantes (ACI) et la version dynamique du modèle de taux de Nelson Siegel (DNS). Une application sur des portefeuilles d'obligations zéro coupons de différentes devises permet d'identifier la diversification des résultats entre les marchés stables européens (comme la France), moins stables (exemple Etats-Unis) et les marchés émergents (tel la Turquie).

La deuxième partie est consacrée au risque de Contrepartie. Récemment, un nouveau capital est requis par les normes de Bâle afin de couvrir ce genre de risque. En 2014, la méthode est publiée : Standardized Approach for Counterparty Credit Risk (SA-CCR). On applique cette méthode sur différents types de produits dérivés afin de comparer le capital demandé par cette approche à celui obtenu par les modèles internes. Les modèles internes incorporent les estimations historiques ainsi que les projections futures du marché tout en se basant sur des modèles bien connus tels que Vasicek et GARCH. Plusieurs structures de hedging sont mises en place afin de mesurer l'impact de chacune sur les deux montants de capitaux requis (sous la méthode standard ou l'IMM). L'effet sur des produits en EUR et USD reflète que le modèle interne demande 80% du capital standard quand aucune stratégie de hedging n'est mise en place. Par contre, le hedging semble être beaucoup plus favorisé par le modèle standard que le modèle interne.

La troisième partie est toujours sur le risque de Contrepartie, mais se focalise sur l'ajustement d'évaluation de crédit (CVA). Ce sujet ne faisait pas partie des capitaux requis sauf récemment àÂ cause de son grand impact durant les récentes crises financières. Dès lors, si une opération avec des produits dérivés ne passe pas par une central clearing houses, un capital pour le CVA est requis. Dans ce travail, on détaille les méthodes acceptées par Bâle afin de calculer ces capitaux et on les compare entre elles. La comparaison se fait en se basant sur des portefeuilles de swap de taux d'intérêts avec, comme contreparties, différents pays d'Investment Grade. Cet article incorpore en plus l'impact de la corrélation entre la détérioration de la qualité de la contrepartie et l'augmentation de l'exposition prévue avec cette contrepartie connue sous le nom de Wrong Way Risk : des modèles de correction d'erreurs (ECM) sont mis en place afin de déterminer ce lien. Les résultats permettent de montrer l'importance d'utiliser les CDS des contreparties et non de se limiter à leur note (Investment Grade ou pas), comme le propose Bâle, afin d'être plus représentatifs de la vrai qualité de crédit de la contrepartie.

Mots clés : Bâle III, Risque de taux d'intérêt, Risque de Contrepartie, Ajustement d'évaluation de Crédit, Wrong Way Risk.

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Contents

Acronyms

ARIMA	Autoregressive Integrated Moving Average
ATM	At The Money
BA-CVA	Basic Approach for Credit Valuation Adjustment
BCBS	Basel Committee on Banking Supervision
BCCL	Banking Control Commission of Lebanon
BDL	Banque Du Liban
BIS	Bank for International Settlements
CAR	Capital Adequacy Ratio
CC	Capital Charge
CCP	Central Counterparty Clearing House
CCR	Counterparty Credit Risk
CDS	Credit Default Swap
CEM	Current Exposure Method
CSA	Credit Support Annex
CVA	Credit Valuation Adjustment
DNS	Dynamic Nelson Siegel
EAD	Exposure At Default
ECM	Error Correction Model
EE	Expected Exposure
EEE	Effective Expected Exposure
EEPE	Effective Expected Positive Exposure
EOM	End Of Month
EPE	Expected Positive Exposure
ES	Expected Shortfall
EUR	Euro
FAQ	Frequently Asked Questions
FAS	Financial Accounting Standards
FOMC	Federal Open Market Committee
FRTB	Fundamental Review of the Trading Book
FX	Foreign Exchange

GARCH	Generalized Autoregressive Conditional Heteroskedasticity
GDP	Gross Domestic Product
HW	Hull and White
HW1F	Hull and White One Factor Model
ICA	Independent Component Analysis
ICAAP	Internal Capital Adequacy Assessment Process
IFRS	International Financial Reporting Standards
IG	Investment Grade
IMF	International Monetary Fund
IMM	Internal Model Method
IMM-CVA	Internal Model Method for Credit Valuation
IR	Interest Rate
IRB	Internal Rating Based
IRR	Interest Rate Risk
IRS	Interest Rate Swap
ISDA	International Swaps and Derivatives Association
LCR	Liquidity Coverage Ratio
LGD	Loss Given Default
MENA	Middle East and North Africa
MF	Maturity Factor
MPOR	Margin Period Of Risk
MTA	Minimum Transfer Amount
MtM	Mark-to-Market
NICA	Net Independent Collateral Amount
NSFR	Net Stable Funding Ratio
OTC	Over The Counter
PCA	Principal Component Analysis
PD	Probability of Default
PFE	Potential Future Exposure
QIS	Quantitative Impact Study
RC	Replacement Cost
RCAP	Regulatory Consistency Assessment Program

RMSE	Root Mean Square Deviation
RW	Risk Weight
SA-CCR	Standardized Approach for Counterparty Credit Risk
SA-CVA	Standardized Approach for Credit Valuation Adjustment
SA-TB	Standardized Approach for the Trading Book
SBA	Sensitivity Based Approach
SD	Supervisory Duration
SF	Supervisory Factor
SFT	Securities Financing Transactions
SM	Standardized Method
SME	Small and Medium-sized Enterprises
TH	Threshold for collateral
UNHCR	United Nations High Commissioner for Refugees
USD	United states dollar
VaR	Value at Risk
WWR	Wrong Way Risk
YTM	Yield To Maturity

Introduction

Lebanon is a small country located on the east of the Mediterranean Sea in the Middle East surrounded by a rather unstable environment. During the last few decades, the region has known several turbulences going from wars in Iraq, to Lebanon, Palestine and now in Syria. Lebanon has currently a population of approximately 300,000 Palestinian and Iraqi refugees, and has welcomed since 2012 more than 1.2 million registered Syrian Refugees (cf. UNHCR, 2015). This situation affected tremendously the Lebanese well-being in all sectors: services, agriculture, industry, etc. However, despite continuing regional imbalances, Lebanon has managed to achieve in 2015 a positive growth of 1% outperforming some of its peer's levels which are still feeling the brunt of the regional economic crisis.

The major player in maintaining this stability in the country is the Lebanese banking sector: characterized by maintaining relatively high liquidity on the market and solid capital adequacy, the banking sector plays a pivotal role in sustaining the country's economy. The Lebanese banking sector is rather unique due to the fact that the financing of the government is mainly relying on commercial banks deposits growth. With a debt to GDP ratio of almost 140%, a very large proportion of this government debt is held by domestic banks, therefore the stability and the adequate management of these latter is a must. Handling adequate management forcibly amends a solid risk management structure capable of insuring a road map for the Lebanese banks activities.

A proof of the Lebanese commercial banks strength is the fact that in the 2016 Banker magazine annual survey of the world 's top 1,000 commercial banks, Lebanon's top ten banks all made the list. Bank Audi led the way for Lebanese banks, this year like the previous, coming in the 350th spot. Bank Audi was followed in the rankings by BLOM Bank (364th), Fransabank (521st), Byblos Bank (526th), BankMed (573rd) (cf. The Banker, 2016).

Bank Audi is a regional bank operating principally in Lebanon offering a very well diversified range of products and services catered to Commercial, Retail and Private clients. Founded in 1830 with initial shareholders of the Audi family together with certain Kuwaiti investors, currently the shareholder base is comprised of more than 1,500 holders of common shares and global depositors receipts. In terms of total assets of around 67 billion Lebanese pound and customers deposits of 54 billion, the bank ranked first among Lebanese peers (cf. Audi, 2016).

Bank Audi is present in the MENA region and few European countries: France, Switzerland, Monaco, Egypt, Jordan, Iraq, Qatar, Saudi Arabia and Turkey. Turkey market was not added to Bank Audi's profile until recently (2012) however since arriving in Turkey just four years ago, Bank Audi has expanded its Odeabank subsidiary to the point where it is Turkey's ninth largest private bank by assets.

Having several branches all over the world, Bank Audi must confirm to the local regulator for each branch (therefore for each country) and on a consolidated basis confirm with the Lebanese regulator. The local regulator is the BDL (Banque du Liban) and it is known to be very restrictive compared to international regulators due to the specificity of our case. A closely related entity to the BDL, however independent, is the BCCL (Banking Control Commission of Lebanon) was found in 1967 to supervise banks, financial institutions, money dealers and brokerage firms. The BCCL evaluates financial soundness of regulated entities through on-site and off-sites review. The review includes monitoring the implementation of the central bank regulations, the BCCL circulars, international accounting standards and the Basel Committee requirements.

The goal of this thesis is to provide Bank Audi with a tool to understand the aspects of managing trading book risks and counterparty credit risk through applying Basel III regulations and contrasting the amended capital charge using these approaches to the one required by more flexible methodologies.

Basel regulations initiated in 1974 with 10 central banks forming the Basel Committee in order to have unified sets of prudential rules and regulations through banks. Increased volatility on financial markets, globalization and the rise of innovative instruments were all reasons for the creation of such international regulator. Since 2009 all G20 countries were part of this committee as well as some major markets such as Hong Kong and Singapore. The initial focus was to set a minimum capital requirement for different types of risks to set a limit for the level of safety and consistency in banks. Since the creation until the time of writing this thesis, four versions of Basel accord are available: Basel I, Basel II, Basel II.5 and Basel III.

Basel I focused on increasing the capital adequacy ration among banks to a limit of 8% (Capital to risk weighted assets ratio) through computing the capital charge using simplistic approaches. This would increase competitiveness among banks and reduce incoherence by raising the risk management discipline. However, it only focuses on one risk which is the credit default risk. It defined the weights per counterparty and the capital requirement adequate to each trade. One major fall-back of this accord is the absence of very important different risk sources and the lack of sensitivities in the computation approaches.

Basel II added to the credit risk two additional risk types: Market and operational risk. Furthermore, Basel II gave banks the option to choose between internally built models (that ought to be more reflective of each bank's situation) or a standardized fit-all approach. Adding to these risk measurement approaches, Basel II introduced the current three-pillar approach: Pillar 1 establishing the minimum capital requirement for the cited three risk types; Pillar 2 is intended to identify additional risks for the bank under the framework of the Internal Capital Adequacy Assessment Process (ICAAP) and a third pillar that aims for a clearer disclosure and fuller transparency on the market by amending full disclosure requirements all across the banks portfolios.

The first impacts of the financial crisis led the way for a new Basel implementation. Basel II.5 added some enhancements to the previous Basel framework on the three pillars levels: for Pillar 1, it amended higher risk weights to better reflect the risk faced and suggested more rigorous credit analyses of externally rated exposures. In Pillar 2, previous weakness that appeared after the financial crises were addressed to better manage long term and off balance sheet exposures. As for Pillar 3, Basel II.5 strengthened requirements specially in the trading book framework and the securitization exposures.

After the 2008 financial meltdown, the Basel Committee found it necessary to build a new, more transparent framework for international banking. The major aims of Basel III were to make banks more 'ready' to face shocks such as the financial crisis, to enforce the risk management process and ensure transparency and appropriate disclosure practices. Therefore in 2011, Basel introduced its third accord and followed with several publications, consultative documents, standards and QIS in order to refine and adjust the new sets of regulations.

Basel III reforms could be summarized by the following (cf. BCBS, 2011):

- Pillar 1:
  - Capital: Greater focus on quality and level of capital, inclusion of a capital conservation buffer, inclusion of a countercyclical buffer.
  - Risk Coverage: strengthening the capital treatment for securitization, demanding a significantly higher capital for trading book instruments, strengthening the counterparty credit risk framework and encouraging the clearance of derivatives trades through central counterparties.
  - Leverage: Adding a non-risk-based leverage ratio that includes off-balance sheet exposures.
- Pillar 2: Supplementary requirements were added to manage risk of off-balance sheet exposures, valuation practices stress-testing, corporate governance and supervisory colleges.
- Pillar 3: Introduction of requirements related to securitization exposures. Addition of details on regulatory capital and reported figures including an explanation by each bank on the method used to compute its regulatory capital ratios.

Another addition to the Basel III framework was the liquidity component through: demanding the liquidity coverage ratio, amending a net stable funding ratio, incorporating several principles for sound liquidity risk management and supervision in addition of supervisory monitoring of this liquidity framework.

Focusing on the trading book and counterparty risk aspects, in this thesis we will observe in detail the Basel documents related to each capital requirement method proposed for these two risk aspects in order to apply it on sample portfolios and compare it with other approaches in order to better assess the regulatory approaches. Therefore we give Bank Audi a full comprehensive view of the regulatory demanded capital and the alternative figures for different computation scenarios.

Note that this thesis is article based, you will find in this document the full version of the work with the chapters 2 and 3 linked to their published articles. On another side note, between the time of starting and ending this thesis several changes were in place due to the dynamic nature of Basel regulations, each part of the thesis follows the rules that were amended at the time of writing the correspondent part. Per example for the second chapter, the work was based on a consultative document that was modified shortly after the publication of the paper. An introductory chapter details the information used in the three following chapters in order to give the background for the approaches used and the market statistics that were present. Chapters 2, 3 and 4 are article written with the first two being already published.

In the first paper (Chapter 2), **'Analyzing and Comparing Basel's III Sensitivity Based Approach for the interest rate risk in the trading book '** published in the *Accounting and Applied Finance Journal (AFA), 2016, 2(1), 89-100* , we focus on the Fundamental Review of the Trading Book (FRTB) approach for computing the capital charge.

In May 2012 the Basel Committee published a Consultative Paper on a 'Fundamental Review of the Trading Book'(FRTB) to improve this framework, then in December 2014, 'Fundamental review of the trading book: outstanding issues '(cf. BCBS, 2014 b), and its comments March 2015, the BCBS exposed the weaknesses of Basel's previous approaches. It suggested some major changes to the trading book to be implemented by 2018: scope and approval process (boundary of the trading book, desk level model approval, model testing, model independent assessment tool), modeling Issues (stressed expected shortfall, liquidity adjustments, diversification, default and migration risk, and non-modelable risk factors), and new standard rules for capital charges computation. In January 2016, a finalized standards paper (cf. BCBS, 2016 a) was published by Basel for the FRTB framework (shortly after our paper).

The rule suggested by the FRTB is based on sensitivities, hence it is called the 'Sensitivity based approach '(SBA): it was implemented as the 'homogeneous' method for capital charge computation across all banks. The SBA is based on percentages and correlations between different maturities and currencies. The existing standard rules poorly reflected hedging or diversification thus inflating the trading book capital level. The SBA is simple yet risk sensitive which is already a big improvement. SBA is a standardized method that reflects the risk resulting from: Interest rate, credit spread, equity, commodity, foreign exchange, options risk and default.

Seemingly, the SBA has several add-ons regarding sensitivity and diversifying considerations however it still has some issues (specifying the coefficients) and details concerning the aggregations that need to be tweaked; for instance the figure under the square root is sometimes negative (cf. ISDA (2015)). In this dissertation, we aim to focus on the suggested standard rule by the FRTB in order to compare it with other econometric models to find an equivalent capital charge computation technique with few additional details such as time horizon and confidence level for a given capital. Among the different risk modulations, we chose to focus on the interpretation of the general interest rate risk capital charge calculation.

Our aim in this work is to understand the computation of the interest rate risk in banks based on Basel's III approach. However, the SBA remains relatively vague and the choices of its coefficient and correlation parameters are not robustly detailed and documented. Hence, studying the interest rate risk from an econometric point of view in order to compare and contrast the results is critical and highly important. We compare the capital charge given by the SBA approach to the capital charge equal to a simple Value at Risk given by several econometrical models on different time horizons.

Based on different central banks approaches for term structure interest rate, we selected few econometric models. The main idea was to reduce the dimensions of the database, study the dynamics of these 'reduced 'factors and then conclude on the wider data range dynamic. We introduce the methods used to derive capital requirement and compare them with SBA's in order to conclude on some equivalence between them.

The structure of the work is as follows: We started by modeling each interest rate curve on a stand-alone maturity basis using a Generalized Auto Regressive Conditional Heteroskedasticity (GARCH) approach. The first-order (p=q=1) GARCH model (cf. Taylor, 1986) has become the most popular GARCH model. It is worth noting that by doing so, we dropped a crucial information which is the strong correlation between these maturities, however we needed this phase as a starting point and a comparison threshold. In another step we used the Principal Component Analysis (PCA) and Independent Component Analysis (ICA) to model the interdependency among tenors. Projecting the data and re-creating the portfolios, we are able to get a VaR based capital charge. A fourth method applied was to project using a Dynamic Nelson Seigel (DNS) Approach and Autoregressive Integrated Moving Average (ARIMA) in order to get the VaR of the portfolios studied.

The capital charge using the previously mentioned methods can be computed on a certain confidence level basis and for a given time horizon; therefore comparing these methods to SBA would determine a common time horizon and confidence level, reaching the purpose of this work.

We start by explaining in details the procedure of the SBA, the correlation between the duration of the portfolios and the capital charge required by this procedure then compare the methods using different approaches. These latter will be based on zero coupon bonds portfolios denoted in: euros, dollars and Turkish lira from the French, German, US and Turkish governments yields respectively, for maturities between 1 month and 30 years.

In the second paper (Chapter 3), **'Counterparty Credit Risk in Derivatives under Basel III '** published in the *Journal of Mathematical Finance (JMF), 2017, vol. 7, no 01, p. 1-38* in a Special Issue on Credit and Further Valuation Adjustments, we focus on the new standardized approach for the counterparty credit risk the SA-CCR application on the derivatives held by a bank (and not the SFTs).

The derivatives market has been blooming since the early 2000s, a huge growth is seen on this market however with this increase in size a decrease of transparency is observed. Over the counter transactions are increasing in size and in riskiness. In a reform attempt from Basel II.5 to Basel III, a new method was proposed to compute the capital charge for the counterparty SA-CCR in the BCBS document (cf. BCBS, 2014 a).

Derivatives hold several types of risks such as market, liquidity and credit, however the credit risk in such instruments is not the typical credit risk that we encounter when passing a loan; it is the counterparty credit risk. The counterparty credit risk differs from the traditional credit risk by two points: The bilateral risk profile and the variation of the exposure depending on market and counterparty behavior. Counterparty credit risk is the risk taking into account the exposure of the financial institution to the counterparty if this latter defaults or has its credit quality devaluated. Recent crises emphasized the faulty practices regarding the OTC derivatives capital charge computation from a counterparty credit risk point of view: Starting with the collapse of Lehman Brothers and several near and full collapses of banks all over the United States, United Kingdom and Europe, the counterparty risk gained now the same importance as the major well-known risks (market, liquidity, operational ...).

Basel standardized approach was presented and revised by April 2014 and is in order to be implemented by January 2017. Main objectives of this method implementation were to be: suitable to be applied on different kinds and specifications of derivatives transactions, easy and simple implementation techniques, better than the methods that preceded and a more risk sensitivity reflection of the reality.

One frequent practice in banks is to hedge the counterparty credit risk by using netting agreements, master margining agreement, demanding collateral... Basel amended for such approaches in its capital computation techniques. This was not the case in earlier version of counterparty capital charge computation methodologies, per example margined or un-margined transactions were not separated earlier. Therefore, the new technique is definitely an improvement on the earlier versions in terms of specificity on the derivatives market.

As usual under Basel framework, a standardized approach and another internal approach are permissible. Having the computation of the capital charge as our main aim we built an internal model and computed the capital requirement under both standardized and internal model in order to reflect the differences and the convergences. The internal model build was based on historical calibrations and market implied variables, incorporating market forecasts such as the Federal Open Market Committee (FOMC) forecasts for the dollar projection. Using a risk free Vasicek calibration (cf. Planchet and Karam, 2013) for the interest rate forecast, and a GARCH (1,1) for the FX rates we were able to construct the expected exposures of the chosen instruments: Interest rate swaps, FX forwards and FX options.

Creating hypothetical portfolios in EUR and USD, computing the capital charges using once the SA-CCR and once the internally built model, we are able to compare and contrast the requirements of both approaches taking into account several hedging scenarios such as netting and collaterization. An brief additional part discussed the impact of the CVA capital charge on such computation.

In the third paper (Chapter 4), **'Basel III Credit Valuation Adjustment Capital Charge and Wrong Way Risk '**, we try to complete the counterparty framework. Basel is encouraging banks to go into central clearing houses in order not to pay the CVA capital charge however, in smaller commercial banks, the majority of the derivatives handled are not centrally cleared (the case for Bank Audi) therefore trying to understand Basel requirements for the Credit Valuation Adjustment (CVA) is a must. We foccused on applications with investment grade sovereigns counterparties.

In its most recent QIS on CVA, February 2016 (cf. BCBS, 2016b), the Basel committee accepted two approaches for modeling the CVA capital charge: the standardized FRTB (SA-FRTB) method and the basic approach (BA-CVA) . The first one being convergent towards the previously discussed market FRTB framework and the second one being a fit-all formula for banks that are not capable of applying the FRTB framework.

BA-CVA is based on standardized computations that do not necessarily need internal model implementation, however the FRTB approach needs a computation of the CVA sensitivities to several risk factors. Therefore, an internal model is necessary to compute the CVA figure and therefore its sensitivity.

One important goal is to compare these approaches for sovereign counterparties, more specifically for investment grade sovereigns and try to see the reflection of the absence of credit rating in these new approaches. Using an internal model based on a Hull and White forecast, we computed the CVA figures and therefore the capital charges.

An important factor that should not be neglected when accounting for the CVA risk is the Wrong Way Risk (WWR) which is the impact of the correlation between the exposure and the credit quality of the counterparty. This relationship should be reflected in the capital charge because it could severely affect the reserve we need to account for.

Using Error Correction Models (ECM) between the swap rates and the Credit Default Swaps (CDS) we are able to translate the impact of a change in swaps on the CDS curves therefore the impact of exposure on the credit quality. Doing so, and discretising our formulas using Monte Carlo simulations we are able to account for the new, wrong way risk including, CVA figure and therefore re-compute the capital charge using the FRTB approach.

Comparison were made based on hypothetical portfolios of interest rate swaps held against three investment grade sovereigns in order to see the impact in the change of the FRTB approach without affecting the Basic Approach. The countries chosen were France, Ireland and Spain. All swaps denoted in euro, the only impact would result from the behavior of the CDS of each sovereign in response to a change in the euro swap curves.

Following this thesis plan, we were able to understand the various impact of the SBA FRTB for different markets, show that under an internal model a capital of 80 % the one amended under SA-CCR is needed and finally for the CVA part, we deducted the impact of wrong way risk for different CDS levels and the effect it would have on the use of the basic approach or the FRTB approach by the bank. Detailing these conclusions, the rest of the thesis is organized as follows: Chapter 1 is a detailed description of the concepts, terminologies and few statistics of the subjects delt with in the thesis, Chapter 2 is the Analyzing and comparing SBA for the general interest rate risk in the trading book paper, Chapter 3 is the counterparty credit risk in derivatives under Basel III paper, and Chapter 4 is the Basel III CVA capital charge and WWR paper.

Chapter 1

Lebanese Banking sector, Derivatives market and Risk Regulations

The aim of this Chapter is to introduce the key concepts we are going to discuss in this thesis and give some indicative figures. In Section 1.1, we present some facts about Bank Audi, its operating environment conditions and key financial reports. Section 1.2 briefly discusses the two major books in a bank and section 1.3 details the risks encountered in a typical commercial bank. Section 1.4 is dedicated to derivatives: their definition, different typologies, pricing techniques and recent international statistics. The last section, Section 1.5, is an overview of the Basel journey: from the first meeting to the most recent Basel IV discussions.

1.1 Bank Audi

As introduced, the objective of this work is to insure a comprehensive tool of the regulatory framework requirements in several banking risks compared to other proposed approaches for the Lebanese commercial bank: Bank Audi. Therefore, we need to start by highlighting the most recent operating environment conditions, the specificity of the market and more precisely the structure of Bank Audi, its main activity streams and risks encountered through the bank's several entities. The MENA region is of main concern for Bank Audi due to its wide presence in different countries of this area, adding to that the Turkish entity (ODEA) that, even being very young, is being able to gain its important rank between the Turkey established banks. All figures and facts discussed in this section can be found in detail in Bank Audi Group 2016 annual report on the group's official website.

1.1.1 Operating environment conditions

A quick geopolitical and economical overview of these regions show important recent turbulences: regional conflicts are taking over a number of countries and low oil prices are mainly affecting the oil-exporting ones resulting in a mild growth of only 3.2% of the MENA's banking sector deposits in December 2016 compared to December 2015. Within this environment, the main presence for Audi are the Egyptian and Turkish market (other than Lebanon), and these latters were also facing challenges: mainly monetary pressures and security threats. November 2016 witnessed a turning point in the Egyptian economy: a decision to move from a fixed exchange rate system to a floating exchange rate system resulted in an Egyptian pound exchange rate of 18.11 pounds per dollar compared to the 7.83 pound per dollar observed no more than a year earlier. As for Turkey increased political uncertainty, decrease in the tourism sector and weak business confidence not to mention the attacks in Turkey's airport and main cities lead to an expected a fall in growth to 2.7% in 2016 as per the IMF, against 6.1% in 2015. In Lebanon, the regional impact is still observed: weak private consumption and cautious behavior from investment is observed. However the real GDP grew by 2% than the previous year and optimistic views are set for upcoming years with the successful election of a president and the union between different Lebanese political parties. Despite these conditions, Bank Audi recorded a 17% raise in its consolidated net profits relative to 2015.

1.1.2 Consolidated financials

Table 1.1: Bank Audi consolidated Balance sheet, December 2016, Source: Bank Audi annual report 2016

Balance sheet (in %)			
Primary liquidity	36%	Bank deposits	7%
Portfolio securities	22%	Customers' deposits	81%
Loans to customers	39%	Subordinated debt	1%
Other assets	2%	Other liabilities	2%
Fixed assets	2%	Shareholders' equity (profit included)	8%
Total assets	100%	**Total Liabilibilities**	100%

Entities outside Lebanon contributed to 41.5% of the consolidated total assets. As seen in the balance sheet the bank continues to favor the asset classes with the highest impact on profitability while diversifying the portfolio and respecting the internally set limits (reviewed annually or when seen necessary).

The Bank's primary liquidity is composed of amounts held at the central banks of the countries of presence of the Group, excluding certificates of deposits issued by the Central Bank of Lebanon, placements with banks and loans to banks, and reverse repo facilities with the Central Bank of Lebanon, other central banks, and financial institutions.

The Bank securities' portfolio is composed of Treasury bills denominated in Lebanese Pounds, sovereign bonds denominated in foreign currency (principally US Dollar-denominated Eurobonds issued by the Lebanese Republic), certificates of deposits issued by central banks where the Bank conducts its operations, non-Lebanese sovereign bonds, other fixed income instruments, and equity securities.
The Bank's loan portfolio consists of direct lending, such as term loans, residential and commercial mortgages and overdrafts. The Bank offers a wide range of traditional banking products and services to large corporate clients, namely working capital finance by way of credit lines, overdraft facilities and short-term loans (with terms of less than one year), and Trade Finance, while also being active in syndications. In addition, the Bank provides support and financing to SMEs.
Banks' deposits include dues to the Central Bank of Lebanon, dues to other central banks of the countries where the Bank operates, repurchase agreements and dues to banks and financial institutions which include term loans granted from various supranational entities for the purpose of financing SMEs in the private sector at subsidized interest rates. A more detailed representation of the consolidated financial position is found below:

Table 1.2: Consolidated Statement Of Financial Position as at 31/12/2016, Source: Bank Audi annual report 2016

Total Assets	
Cash and balances with central banks	27.9%
Due from banks and financial institutions	4.5%
Loans to banks and financial institutions and reverse repurchase agreements	3.1%
Derivative financial instruments	0.6%
Financial assets at fair value through profit or loss	1.0%
Loans and advances to customers at amortised cost	38.6%
Loans and advances to related parties at amortised cost	0.3%
Debtors by acceptances	0.3%
Financial assets at amortized cost	21.0%
Financial assets at fair value through other comprehensive income	0.3%
Investments in associates	0.0%
Property and equipment	1.3%
Intangible assets	0.1%
Non-current assets held for sale	0.1%
Other assets	0.7%
Goodwill	0.1%
Total assets	100%
Total Liabilities	
Due to central banks	3.0%
Due to banks and financial institutions	3.9%
Derivative financial instruments	0.4%
Customers' deposits	80.0%
Deposits from related parties	1.2%
Debt issued and other borrowed funds	1.5%
Engagements by acceptances	0.3%
Other liabilities	1.2%
Provisions for risks and charges	0.2%
Total liabilities	91.6%
Shareholders' equity	8.4%
Total liabilities and shareholders' equity	100%

Aiming to study the counterparty risk encountered in the derivatives traded by the bank we detail the following financial instruments.

1.1.3 Derivative Financial Instruments

Bank Audi Group uses derivatives such as interest rate swaps and futures, credit default swaps, cross currency swaps, forward foreign exchange contracts and options on interest rates, foreign currencies and equities. Derivatives are recorded at fair value and carried as assets when their fair value is positive and as liabilities when their fair value is negative. The table below show the percentage of total notional amounts analyzed by the term to maturity.

Table 1.3: Derivatives held for trading, Consolidated figures as 31 December 2016, Source: Bank Audi annual report 2016

	Notional amount	< 3 months	3 months < 1 year	1 year < 5 years	> 5 years
Forward foreign exchange contracts	7.00%	81%	18%	1%	-
Forward precious metals contracts	0.004%	100%	-	-	-
Currency Swaps	33.51%	84%	9%	6%	-
Precious metals swaps	0.34%	89%	11%	-	-
Currency options	28.08%	63%	37%	-	-
Interest rate swaps	19.94%	1%	14%	76%	9%
Interest rate options	0.83%	-	-	100%	-
Credit default swaps	10.14%	7%	31%	62%	-
Equity options	0.16%	-	-	100%	-
Total	100%	53%	21%	25%	2%

Note that most of the Group's derivative trading activities relate to deals with customers which are normally offset by transactions with other counterparties.

1.2 Banking vs trading book

Trading and banking book are accounting terms that categories instruments in a bank: Based on the purpose the bank is holding this product, a decision is made whether it is in the banking or the trading book. We note that the distinction between these two books is rather ambiguous in some cases, to confirm, some financial institutions have used this to juggle products between this or that book in order to reduce the capital charge or enhance the capital adequacy ratio.

The trading book, as its name shows, refers to all assets held by the bank and that are regularly traded, it is required to be marked to market daily. The banking book however, is the assets that the bank is supposed to hold until maturity. It is not marked to market. Adding to that, the value-at-risk in both books is at the 99% confidence level, however due to the purpose of the instruments held the time horizon is taken as a one-year for the banking book however it is a 10-days horizon for the trading book instruments.

1.3 Banking Risk Management

Financial risk management has known a large boost over the last decades due to consecutive sever crisis that emphasis the crucial need of having a robust, well planned risk management function. Corporations need to manage their risk rather than avoiding them: quantitative approaches have been widely adopted however a full reliance on these figures without considering the exogenous conditions a financial institution is exposed to would not be very representative.

In banks, financial risk is divided between several types: market, credit, operational and more recently liquidity. Briefly, we introduce each type.

Market Risk is due to market prices movement: stock prices, FX rates, interest rates, commodity prices or credit spreads. It is this, overly studied risk, that led to the birth of the value-at-risk concept. Previous studies show that the market risk factor dominates in term of statistical significance on the entire portfolio risk (cf. Rosenberg and Schuermann, 2006). One main focus point of the market risk is the interest rate risk. A bank's interest rate risk reflects the extent to which its financial condition is affected by changes in market interest rates. There are two different ways of thinking about such effects. The first approach focuses on the impact of changes in market interest rates on the value of bank assets, liabilities and off-balance sheet positions (potentially including those that are not marked to market for reporting purposes). The second approach focuses on the implications of movements in market rates for the future cash flows that the bank will obtain. Since the present discounted value of the banks cash flows must equal the economic value of the bank, these two approaches are consistent and can be both useful.

To assess directly the extent, detailed information about a number of possible sources of interest rate risk is needed. Clearly, one would need to understand the mechanism of the bank and the detailed characteristics of each product: pricing assets and liabilities, including repricing periods and base rates, the likelihood that bank customers would choose to repay loans or withdraw funds early as a result of changes in market rates, the interest sensitivity of fee income and off-balance sheet exposures... In addition to being very complex, the feasibility of this study depends on the availability of the data therefore we try to choose an alternative way by resorting to well-chosen benchmarks.

The credit risk is related to a counterparty: this latter might not be able to fulfill his contractual obligations: as default or just devaluation of the required amount. A potential default of the borrower or the counterparty in a derivative transaction give rise to this type of risk. The key aspect in this type is therefore the probability of default, the expected exposure at time of default and the amount that the bank anticipates recovering in such events.

Operational risk is divided among different sources: people, systems and external events. An employee fraud, an ATM malfunction or a civil war fit in the operational risk category. This is the most hard risk aspect to be quantified which leads banks and regulators to the use much more qualitative techniques, score cards and professionals assessments rather than mathematical models.

Liquidity risk represent the risk that a transaction cannot be executed on the market due to the illiquidity of the underlying or size of the transactions or the risk of not being able to fund payments. This risk gained the notation of the 'death risk' in 2008 crisis once liquidity is missing it's a vicious circle not only for the concerned institutions but for the whole system.

1.4 Derivatives

1.4.1 What is a derivative?

As the name indicates derivatives are financial instruments that derive their value from another underlying asset (cf. Sundaram and Das, 2011) such as interest or foreign exchange rates, equity, commodity or measurable events such as the weather or the rainfall averages.

In addition, these derivatives could be found on the market in several forms: different types and therefore different specifications. The possible typologies of derivatives are: futures, forwards, swaps, options, structured debt obligations and deposits, and various combinations thereof.

One very rich reference about derivatives is John Hull's book (2006), it permits interested readers to understand all simple and complex typologies of derivatives through defining, pricing and valuating them.

1.4.2 Different derivatives typologies

Forward contracts A forward contract is the most basic type of derivatives: it is a deal between a seller and a buyer to purchase a certain good or service at a future date at a price agreed upon at inception without the right of cancellation of the deal.

Future contracts A future agreement is also a deal between a buyer and a seller on a purchase at a fixed price however, futures are more regulated than forwards: organized exchanges, fixed dates, pre-defined frequencies of settlements... Comparing between future and forward instruments is made clear in Jarrow et al. work (1981).

Options Options can be call or put: A call is an instrument that gives the right and not the obligation to buy a certain asset at a given price (pre-agreed upon) and the put gives the right to sell at a predefined price. The type of an option depends on the underlying asset: If it is an interest rate, we are dealing with an interest rate option if it is a foreign exchange currency rate the option is called an FX-option. Same principles apply for both cases.

Swaps A swap is an agreement between two parties that permits the exchange of cash-flows at inception, at maturity and between these two days following an agreed-upon schedule. The most commonly used types of swaps are the interest rate swap and the FX swap. Interest rate swap is here to permit two players to exchange fixed or floating rates. FX swaps entail swapping between currencies to fit the needs of the two counterparts in the deal (cf. Flavel, 2010).

If additional details is needed consult Redhead (1997) work for an introduction to financial derivatives.

1.4.3 Over the counter vs Exchange traded instruments

Derivatives could be traded in two main ways: exchange traded and over the counter traded (OTC). Exchange traded derivatives, started in 1970, follow certain rules and are ‘standardized’ instruments whereas OTC market, since 1990, is an ‘irregular’ market with various ‘particular’ cases making it more vulnerable to risks (cf. Weber, 2009). OTC market has a larger volume than the exchange traded market due to the OTC market having higher profit margins and wider bid-ask spreads that are often transacted in situations where only one party has a good knowledge of their actual value. However in fact, an exchange traded deal is always safer: the standardization and the lower likelihood of default associated with exchange-traded contracts, relate to the fact that exchange-traded contracts are cleared and settled by a clearinghouse.

A clearing house is a third party between the buyer and the seller who’s role is to ensure several conditions regarding the given transaction (cf. Gregory, 2010):

- Give all the counterparties a garantee not to have any open positions in the market.
- Force the applications of the agreed upon rules for a more liquid market.
- Provide a proper risk management system by using margins and daily accounting’s.
- Ensure all deliveries and processes are consistent in terms of quality, quantity, size so that there is no confusion among parties, in other words all contracts are standardized.

Based on the above we can highlight the importance of clearing houses for a smoother and more compliant derivatives market. That is a main reason why in recent publications, the international banking regulator is encouraging the clearing of all derivatives through clearinghouses.

However, by using these entities, a bank is actually increasing its risk towards it; is it robust enough? In other words, when one puts all his eggs in one basket, he would better make sure that this basket is solid enough to hold all his products, else wise he would have kept them in separate containers. A sorrow description of this issue is handled in Gregory’s book on central counterparties (cf. Gregory, 2014).

1.4.4 OTC derivatives statistics

Basel publishes each 6 months a statistical release on different subjects: OTC derivatives statistics is among these subjects. Following graphs are extracted from the Basel document (cf. BIS, 2015), showing the distribution of the derivatives notional amount and gross value based on different criteria:

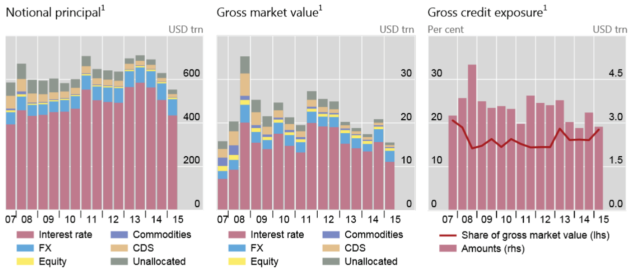

Figure 1.1: OTC derivatives statistics end-June 2015, source: Basel Statistical release BIS (2015)

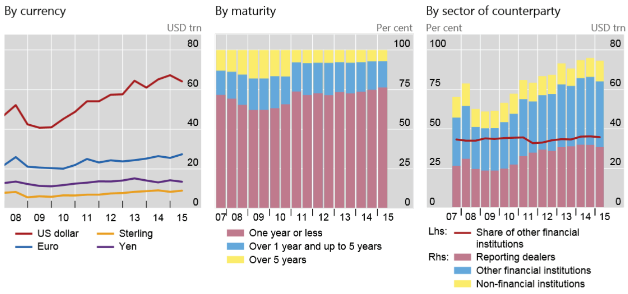

Figure 1.2: Notional of FX derivatives end-June 2015, source: Basel Statistical release BIS (2015)

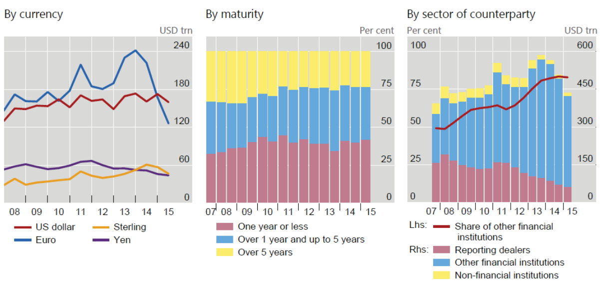

Figure 1.3: Notional of IR derivatives end-June 2015, source: Basel Statistical release BIS (2015)

Therefore we can see that the OTC market is divided between several types of derivatives, divisions and concentrations are shown below:

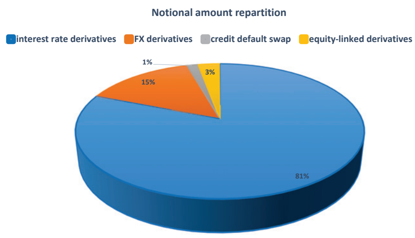

Figure 1.4: OTC repartition

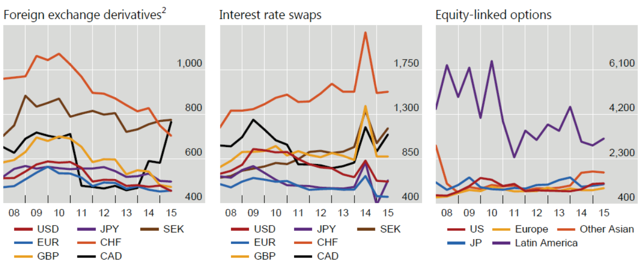

Figure 1.5: Concentration of OTC derivatives end-June 2015, source: Basel Statistical release BIS (2015)

The following table resumes the main ideas of the statistical release of November 2015 based on the OTC market data up until June 2015 (cf. BIS (2015)).

				End-december 2014 (in trillions)	End-June 2015 (in trillions)	Variation pourcentage change	Causes
Global level	Notional amount	Global Notional amount	↓	$ 629.00	$ 553.00	13.7%	Trade compression to eliminate redundant contracts.
	Gross Market Value	Gross Market value	↓	$ 20.90	$ 15.50	34.8%	Reduction in national amounts outstanding. Increases in long-term interest rates (yields closer to swaps').
Interest rate derivatives	Notional amount	denoted in EUR	↓	$ 167.00	$ 126.00	32.5%	Trade compression to eliminate redundant contracts.
		denoted in USD	↓	$ 173.00	$ 160.00	8.1%	Trade compression to eliminate redundant contracts.
	Gross Market Value	Gross Market value	↓	$ 15.60	$ 11.10	40.5%	Increases in long-term yields narrowed the gap between market interest rates on the reporting dates and at inception.
	Notional amount Distribution by maturities	Short-term contracts (T<1y)	↑	40%	42%	4.8%	
		Medium-term contracts (1y<T<5y)	↓	37%	35%	5.7%	
		Long-term contracts (T>5y)	→	24%	24%	0.0%	
	Notional amount Distribution by counterparty	Between dealers	↓	$ 70.00	$ 61.00	14.8%	
		Between dealers and other financial institutions	↓	$ 421.00	$ 360.00	16.9%	Trades were moved to CCp facilating the compression process.
FX derivatives	Gross Market Value	Gross Market value	↓	$ 2.50	$ 2.90	13.8%	Contraction by contracts involving the US dollar and yen.
	Notional amount Distribution by counterparty	Between reporting delears	↑	$ 31.00	$ 33.00	6.1%	
		With financial counterparties	↑	$ 33.00	$ 32.50	1.5%	
Credit default swaps	Notional amount	Notional amount	↓	$ 16.00	$ 15.00	6.7%	
	Gross Market Value	Gross Market Value	↓	$ 453.00	$ 583.00	22.3%	
	Notional amount Distribution by counterparty	inter-dealer activity	↓	$ 7.70	$ 6.50	18.5%	
		With banks and securities firms	↓	$ 1.30	$ 1.20	8.3%	
	Central clearing	Central clearing	↑	29%	31%	6.5%	Regulators ammendment. Less capital charge requirements.
Equity-linked derivatives	Notional amount	Notional amount	↑	690%	750%	8.0%	
	Gross Market Value	Gross Market Value	↓	61%	60%	1.7%	

1.4.5 How to price these instruments?

A derivative is an instrument that gives the option or the obligation to buy and/or sell the same asset on two different markets: the spot and the derivatives market. Any imbalance between these two markets will create an arbitrage opportunity therefore, for a correct pricing of any derivative contract the spot price, the reference rate and the derivative price will be correlated in such a way that makes arbitrage impossible (cf. Kolb and Overdahl, 2010).

Based on that a derivative is priced by simply computing the net present value of the potential cash flows that it would generate (certainly or not). Typically there is two ways to price a given instrument: either by marking to Market or by marking to Model.

The selection between these two approaches is only determined upon the availability of market data for the given product. Per example, treasury securities, banks and corporate bonds (cf. PwC, 2014) are determined by reference to observable quotes obtained in the secondary market therefore the prices are either obtained from brokers or via price providers such as Bloomberg or Reuters. Secondary market indications should be reliable for pricing however, we need to be aware of the specifications of the given price.

However, when trading volumes are not significant or had been through a rough change, when the market is illiquid or even when a product is very complex and bears unique characteristics the price redeemed by brokers or consensus price providers may not be reliable indication of the derivative value, in that case marking to market would not be adequate and a mark to model approach will take place.

To Mark to Model is to price the cash flows based on internally build curves (and not observable on the market). We note that such approach would increase the model risk due to the complexity of determining a money market yield curve on a illiquid market or an issuer yield curve for one particular product and many other obstacles.

1.4.6 Derivatives in the banking sector

A bank is an entity with highly volatile exposures to several risk factors such as interest rate, commodity, and currency risks therefore it needs effective ways to manage its exposures. Derivatives can provide a very efficient tool to hedge such exposures on the off-balance sheet level (OTC derivatives). Derivatives are flexible instruments that could easily hedge a given amount for a given time frame (cf. Shiu et al., 2010).

The bank's characteristics influence the extent of hedging activity (cf. Sinkey and Carter, 2000): it is found that bank common stocks are sensitive to interest rate effects. In addition, banks with a larger element of international activities are more likely to face and accordingly manage their currency exposure (cf. Allayannis and Ofek, 2001). Stulz and Smith (1985) predict that increases in option holdings should be associated with less hedging. It is logical to add that banks with high profitability profiles tend to have a larger use of derivatives in order to hedge their positions and due to the possibility they have in speculating. However, smaller banks would not be able to have the same statues and would use less derivatives, in a lack of interest for speculations and a policy of risk assumption (cf. Goldberg, 1998).

It is important to note that these derivatives might not correspond to a certain banks policies and orientations therefore the issue of using or not derivatives should be negotiated depending on the bank's conditions and its portfolio's composition (cf. Hentschel and Kothari, 2001).

Frequent usages

At the start, derivatives were created in order to hedge high volatility assets and speculate in a gain-making vision for measurable events such as the weather (specifically in the agriculture field). Since then, derivatives have gain a major role on the financial market due to the expansion of their usages: reducing business risks, expanding product offerings to customers, trading for profit, managing capital, funding costs and altering the risk of a particular item (cf. Grecy et al., 1997).

Adding to these global uses of financial derivatives, one could choose to be more specific for each type of these instruments: an FX derivative is crucial for banks that handle different currencies and several international subsidiaries (cf. Adkins et al., 2007 and Brown, 2001), whereas swaps might be justified when timing gap is present (cf. Carter and Sinkey, 1998), etc...

Encountered risks

In 1996, the Office of the Comptroller of the Currency defined nine types of risks related to derivatives instruments in the banking sector (cf. OCC and FRB, 1996): pricing, strategical, reputational, foreign exchange, liquidity, interest rate, credit, transaction, and compliance risks. Note that these risks are not exclusive: one derivative can affect several types of risks. Plus, derivatives risks should be managed based on all these categories: risk consolidation is very important because the various risks contained in derivatives and other market activities can be interconnected and may transcend specific markets.

- One big issue in the OTC market is the vulnerability to systemic risks: lack of transparency to market participants or to regulators can lead to major disasters due to trading in mysterious conditions.
- Market risk is the risk that the value of a transaction will be adversely affected by fluctuations in the level or volatility of the underlying assets or the relationship between one or more market prices, rates or indices adding also other market factors such as illiquidity in the market for the relevant transaction or in a related market for the underlying product.
- Operational risks occur from human error or control systems failure of control systems. In OTC market these risks are implied in several processes such as the specification of standardized contract terms, procedures for physical settlements, valuation methodologies...
- The major risk associated to the OTC market is the counterparty risk: a counterparty will not satisfy its obligations under the contract. The remainder of this work will focus on this specific risk category.

Following the financial crises of 2008, several publications blamed the derivatives for the huge losses encountered (cf. Stulz, 2014). This is highly correlated with the poor judgments made regarding these instruments and the non adequate risk management and internal models calibration for the derivatives. For a review of the role of derivatives in the case of Bear Stearns and Lehman Brothers, see Schultes et al. (2008).

1.4.7 Definitions and terminologies

In his book on Counterparty Credit Risk, J. Gregory (2010) defines all terminologies and concepts related to this typology of risk, in the following a brief overview of the key concepts that we are going to use later on in order to compute the capital charge for this given risk.

Mark-to-market, Replacement cost and Exposure

Mark-to-Market (MtM) This is our potential loss today: The value of an instrument held today on the market reflects the amount the buyer is going to be losing in case his counterparty defaults.

Replacement cost (RC) The replacement cost terminology is almost always confused with the mark-to-market notion, however in an illiquid market the difference could be important.

Exposure This is the feature that gives the derivatives their specificity: the exposure relies a lot on the MtM. If it is positive this amount will represent the loss however, if it is negative, no contribution is needed. Asymmetric risk profile is created, volatility will be key.

Potential Future Exposure The concept of potential future exposure (PFE) arises from the need to evaluate the derivative in the future. The PFE is defined after computation of the expected exposure, simulating as many as possible, generating the average, a non-decreasing average than computing the future exposure for different points in time in order to generate the PFE.

Netting

Netting is the possibility to add the values of different transactions with one given counterpart based on a bilateral agreement. An introductory example would be to suppose party A has five transactions with party B of respective current values: +700, -400, +500, +200 and -600. If no netting is applied the total exposure of party A would be: + 1400 (summing only positive exposures), whereas in case of a netting set agreement the exposure would be the algebraic sum of all transactions giving: + 400. This shows the beneficial addition of a netting agreement.

In regular businesses, it is usually rare to have bilateral contracts with the same firm: we either buy or sell a product or a service from one given firm. This fact makes the netting concept rarely applicable. However, in the derivatives markets we often have a large number of bilateral transactions between counterparties therefore netting is almost always applicable: In case of a netting agreement between the counterparties, each one of them is granted the right to offset all the amounts in the instance of a certain counterparty defaulting.

We note that for a netting to be beneficial there must be a given probability of the instrument having a negative MtM at some point in time. From several mitigation methods, netting is known to be the mostly used structure: The expansion and greater concentration of derivatives markets has increased the extent of netting from around 50% in the mid-1990s to close to 100% today. Plus, this technique is widely beneficial in the derivatives markets: at the end of 2008, netting reduced OTC exposures by 88.7% among US commercial banks (cf. IMF, 2009).

A netting set is the set of trades that are regally netted together under one netting agreement setting the general terms between counterparties. A netting set could contain only one trade and with a given counterparty several netting agreements could be signed. Netting is implemented by ways of a 'netting agreement' which is a legal document that must be applied in case of bankruptcy.

As for every mitigation technique netting has its pros encouraging practitioners to use it, we briefly cite them here below:

- Reducing exposure
- Exiting unwanted positions (by entering an opposite deal and netting)
- Gaining stability

Margin agreement

A margin agreement is an agreement where the first party would have to supply a given product (collateral) to the second party when the exposure of this latter exceeds a certain limit.

The typically used collaterals are: cash, high-quality government and central bank securities, high-quality corporate/covered bonds, letters of credit, guarantees, equity in major stock indices and gold. The most common form remains cash collateral with a 73% majority of USD and EURO denominated trades.

Collaterization volume has been going an upward trend since 2003: around half of OTC derivatives are collateralized. Several causes motivate the usage of collaterals such as reducing exposure, increasing business with given counterparties or reducing capital requirements.

It is important to highlight that even if the main purpose of the collateral usage is to reduce the risk exposure, these procedures might imply the exactly opposite effect: handling collaterals will add market, operational and liquidity risks therefore such practice should be handled with extreme care.

The margining of a trade is not obligatory however when present it should be regulated by an international swaps and derivatives association (ISDA) agreement that will govern different aspects of the margin agreement (cf. Brigo et al., 2013) and account for all possible scenarios by explicitly pointing the following:

- The method and timings of the underlying valuations.
- The calculation of the amount of margin that will be posted.
- The mechanics and timing of margin transfers.
- Eligible margin.
- Margin call frequency: daily margining is recommended however operational cost should be taken into account when defining the adequate frequency.
- Margin substitutions.
- Threshold: the level of exposure below which collateral will not be called and when exposed to a higher exposure than the threshold only the incremental exposure is collateralized.
- Independent amount: referred to as initial margin is the amount posted at the beginning and which is independent of any other collateralization. Usually it accounts for the fact that a certain counterparty could have a much larger exposure than the other.
- Triggers that may change the margin conditions such as ratings downgrades that may lead to enhanced margin requirements, credit spread movement, market value change...
- Minimum transfer amount: it is the minimum transferable amount of collateral that allows operational costs reduction for minimal insignificant amounts of collateral.
- Possible rehypothecation (reuse) of margin securities.
- Dispute resolution.
- Haircuts applied to margin securities.

In his book on counterparty risk, John Gregory illustrated the margin concept using a mortgage example, I found this example very representative and easy to grasp therefore I am going to repeat it in order to specify the function of each concept related to the collateralization hedging technique.

When putting a mortgage on a house, the mortgage lender faces the risk that the mortgagor will not respect his future engagements however, he is ‘covered’ against this risk by the fact that the house is the margin or collateral in that case: if no payment is made the house is kept to the lender. This is the general concept: the house against the certainty of future payments. Still, on a more realistic scale, different additional risks and situations may arise.

As for the sub-prime crisis, the value of this collateral (the house) might decrease until reaching a level lower than the value of future payments: in financial terms this is the ‘market’ risk.

Another encountered issue is the legal obstacles that prevents the mortgage lender to take ownership of the house in case the borrower defaults:this is ‘operational’ or ‘legal’ risk.

There is never a guarantee making the sale of the house a certain event, maybe there is no available clients on the market therefore the value will decrease shortly after putting it to sale: this is the ‘liquidity’ risk.

In practice, a margin agreement follows four major steps:

- Negotiating and signing a credit support annexe (CSA).
- Continuous evaluation of the MtM of the concerned trades and collaterals.

- When negative MtM occurs, the designated counterparty delivers margin.
- Changing the margin afterwards to reflect the transfer of cash or securities.

1.5 On Basel regulations

Since 1988 up until 2017, Basel accords marked the regulatory framework of international banking evolving with every new financial and economical background. In order to fully understand the most recent implementations, rules and focus points it is necessary to understand the background of this regulatory environment. What are the Basel accords? What is their purpose and how did they evolve in the last 40 years?

In 1974, Herstatt bank, a German Bank largely involved in the foreign exchanged activities, failed leading the banking sector to important losses. This case was the red flag that pushed banks regulator into taking action (cf. Goodhart, 2011). Peter Cooke, England bank governor, proposed to unite central banks governors from the G10 countries (France, Belgium, Canada, Italy, Japan, Luxembourg, Germany, Netherlands, Switzerland, Spain, Sweden, United Kingdom and United States) in the Swiss region, Basel, in order to discuss current banking situation. This work group was named the Committee of Banking Regulations and Supervisory Practices, known afterwards as the Basel Committee on Banking Supervision (BCBS).

Having as main objectives boosting financial stability through banks worldwide and increasing communication and cooperation between member countries on banking practices, the Committee held regular meetings four times a year since February 1975. Today, up from the 10 initial participant countries, members of the Basel Committee are equal to 45 institutions from 28 jurisdictions: Argentina, Australia, Belgium, Brazil, Canada, China, European Union, France, Germany, Hong Kong, India, Indonesia, Italy, Japan, Korea, Luxembourg, Mexico, Netherlands, Russia, Saudi Arabia, Singapore, South Africa, Spain, Sweden, Switzerland, Turkey, United Kingdom and the United States (cf. BCBS, 2016).

Initiating the work with a first general framework known under the name 'Concordat', the Committee has published since several standards, white papers, consultative documents and quantitative impact studies in the aim of constructing new Basel accords namely: Basel I, Basel II, Basel II.5 and most recently Basel III.

The 'Concordat' aimed on clarifying the responsibilities among banks branches, subsidiaries and parent departments.The 'Concordat' also required that all banking institutions should be supervised: It defines the adequate consolidated supervision of a bank by the local supervisory authority and the subsidiaries (host) regulatory authorities. The first version was revised in 1983 and in 1990 a supplement was added to increase again prudential measures. In 1996, a new document proposing rules on cross-border banking and enhanced home to host supervisory relationships was endorsed by 140 countries.

Now that the basics of international activity through banks is established, a focus on efficient capital adequacy framework was the principal purpose of the BCBS. They needed the bank to have a sufficient amount of capital not to go into bankruptcy and therefore provide individuals and businesses with the confidence in the stability of the banking sector. Starting with a first accord up until the third, each version was triggered by either a situation on the market that amended intervention of regulators, or by shortcomings of the previous accord version that revealed through practice and implementation.

1.5.1 Organization of Basel publications

Through the years, in one given Basel framework or in between frameworks, the Basel Committees present their works through different types of documents: Consultative, Final, Frequently Asked Questions (FAQ), Report, Newsletters, Working papers, Quantitative Impact Studies (QIS) and comments received from banks worldwide.

Main documents are the consultative ones, final versions, FAQ and the reports. The consultative documents are preliminary versions of proposed changes or additions in the Basel rules: an example is the consultative document for the fundamental review of the trading book. After several consultative documents and following the comments of all interested banks, a finalized document is published: this will be the rule book of the discussed topic. FAQ, as their name indicates, are papers used to answer widely discussed points of a given topic and the reports indicate the work progress into the implementation of the final documents.

The other types are very important as well but are seen as sources of information rather than implementation standards: newsletters and working papers are released frequently to clarify the policies and the methodologies. Comments from the banks are the main source of transition between consultative documents and finalized standards. Finally, the QIS are quasi-continuously held to monitor the impact of the changes in different banks under differing regulations and situations (cf. Penikas, 2014).

These publications are all available on the official site of the Basel for International Settlement (BIS) *www.bis.org* under research and publications. The issues handled in this thesis fall under the banking committee work therefore the adequate publications could be found under the Basel Committee on Banking Supervisions. The papers are sorted per type, date published and status.

1.5.2 Basel I

In the early 1980s, a major international financial crisis initiated in the Latin American region due to sovereign defaults on their debt repayments: Countries such as Brazil and Argentina borrowed up to 50% their GDP to fund the industrialization wave however, in the mid seventies, oil prices went up causing tremendous costs for these countries. This situation slowed down all the economy and was a main pillar for the Basel Committee increasing concerns on capital adequacy in the banking sector in such a growing international risky environment. The result: In December 1987, the first Basel accord was approved and shared with banks: 'Basel Capital Accord'. The main focus of this version was building an adequate credit risk measurement approach and fixing a minimal capital to risk weighed assets ratio of 8% through all banks.

Prior to that agreement, banks were regulated each by its local authority forcing a certain minimum level for the ratio between capital to total assets. However, the definition of the assets and capital included were not unified among regulations and that was the purpose of the Basel implementations. Released in 1988, and scheduled to be implemented in 1992, this first Basel framework was intended to be implemented to all countries with international banking sectors.

Additional amendments to the accord defined the conditions on inclusions in the CAR (Capital Adequacy Ratio) and the netting effects impact were added in 1991 and 1995. Moreover, in January 1996, Basel tried to widened the scope of the first accord by not only covering the credit risk but adding the market risk into the framework (cf. Hull, 2012). One important addition was the fact to allow banks to use their internal models in the computation for the market risk capital requirements.

The 1988 Accord has been subject to many criticism as being too simple or too non-risk sensitive. However, it was able to implement at early stages many important requirements from banks. Based on this first attempt, in 1998 Basel started working on a new, improved, capital requirement framework.

1.5.3 Basel II

June 1999 witnessed the creation of a new capital adequacy framework that was released in 2004 known as 'Basel II: the revised capital framework'. The purpose of this second accord was to improve the way capital requirement reflects a banks' specific situation. Basel II framework started in 1999, was revised between 2001 and 2003, a final set of rules was released in 2004. However several updates and quantitative studies were continuously put in place until 2007.

Basel II is divided into three pillars: a minimum capital requirement, a supervisory review of internal assessment process and a full disclosure panel to encourage transparency on the global market and improve market discipline. In the first Pillar, the credit risk takes into account now the credit worthiness of the counterparty through credit ratings whereas the market risk remains as applied in the first Basel accord framework. The 8% ratio remains unchanged too. Pillar 2 emphasizes the role of local authorities and the importance of their intervention in case of problems. Under Pillar 3, banks are required to disclose information on the way they compute their capital and assess their risk, making them more exposed to their shareholders and urging them to be more cautious with their decision making and risk management techniques.

1.5.4 Basel II.5

Even before the start of the credit crisis, the need for a fundamental change in the regulatory framework was obvious. The severe financial crisis of 2007-2009 emphasized this as a primordial necessity. Mainly, changes in the market risk capital computation in Basel II had to be put in place. Basel II.5 was therefore created and due to be implemented end of year 2011. Three changes were covered under the Basel II.5 framework: the calculation of a stressed VaR for market risk capital requirements, a new incremental risk charge and a risk measure for instruments depending on credit correlation. All three measures combined greatly increased the required market capital charge.

1.5.5 Basel III

After the severe financial crisis of 2007-2009, the Basel Committee realized the importance of creating a new framework for the regulations. The first proposal was published end of year 2009, followed by several comments, consultative documents and impact studies the final version know as Basel III was published in December 2010. Since that date up until today, many revisions are being made to the Basel III accord, new standards are added and numerous impact studies are still being processed. The implementation is scheduled between 2013 and 2019.

Based on Hull's book (cf. Hull, 2012), there are six parts to this new regulation: Capital definition and requirements, capital conservation buffers, countercyclical buffers, leverage ratio, liquidity risk and counterparty credit risk. Being the currently applied framework, we are going to detail each of these six points.

Capital definition and requirements: Under both previous accords, the capital was divided into tiers and each Tier had a certain definition. In Basel III the capital is divided between Tier 1 equity capital, additional Tier 1 capital and Tier 2 capital. Previously used Tier 3 capital is no more. Basel III changed the definition and the requirements for each of these tiers. Tier 1 capital now consists of share capital and retained earnings, additional Tier 1 capital consists of non cumulative preferred stocks and Tier 2 capital includes subordinated debt. As for the requirements, a transitional agreement has been put in place: Tier 1 equity capital and total Tier 1 capital must be 3.5% and 4.5% respectively by January 2013; 4% and 5.5% by January 2014 and 4.5% and 6% by January 2015.

Capital Conservation buffer: Adding to the conventional capital required, Basel III amends for an additional buffer consisting of 2.5% of the risk weighted assets. During non-crisis times, it should be relatively easy for banks to raise capital therefore, the function of this new buffer is to be present in normal times in order to cover losses when crisis strike. Note that additional layer of common equity, when breached, restricts payouts in order to meet the minimum common equity requirement. This conservation buffer will be phased-in progressively from January 2016 up until becoming fully effective in January 2019.

Countercyclical Buffer: It is another capital buffer however, its implementation is at the discretion of the local authorities. It can be set between 0% and 2.5% of the total risk weighted assets in order to account for the cyclicality of the banks earnings. Some countries are demanding a greater ratio than the one amended by Basel for this buffer due to the close correlation between major banks and the economy of the whole country.

Leverage ratio: Leverage was an important cause of the subprime crisis. Banks had been carrying huge leverage ratios that caused their default. Therefore, in this new framework, Basel specified a minimum leverage ratio of 3%: capital to total exposure. This includes all on-balance sheet assets and off-balance sheet exposures. This ratio will also be phased in gradually through time: finalized in January 2014 the implementation is expected to be introduced in January 2018.

Liquidity Risk: Focusing on having enough capital led banks to a major imprecision: capital could be available and sufficient however, liquidity might be the problem. The subprime crisis was a strong proof of this idea: liquidity shortage made it impossible for banks to cover their dues. As an enhancement, Basel III introduced two liquidity ration designed to make sure that the liquidity profile of a bank is strong enough: the Liquidity Coverage Ratio (LCR) and the Net Stable Funding Ratio (NSFR). The LCR is a short term coverage ratio (30 days period) whereas the NSFR is a long term liquidity management ratio (one year). The LCR will be phased in in January 2015 with a minimum threshold of 60% raising linearly per annum to reach a full 100% by the beginning of 2019. The NSFR, takes effect in January 2018.

Counterparty Credit Risk: Again, another conclusion from the subprime crisis was the major gaps that should be filled in the counterparty credit Risk area especially when dealing with non cleared instruments. As a response, Basel III amended a new approach for computing the counterparty capital charge taking into account a more granular approach towards the hedging techniques that could be used encouraging banks to margin their deals. Another improvement was the implementation of an additional capital charge for the credit valuation adjustment (CVA) due to the variability of market factors and credit spreads of counterparties. This capital charge is only applicable when no central clearing is put in place, conducting all banks to eventually clear their derivatives portfolio.

Having many new implementations in Basel III, in January 2012, the Regulatory Consistency Assessment Program (RCAP) was initialized to monitor and asses the implementation of Basel III standards. A long time schedule is needed for all these implementations to be put in place, to help ease the transfer a set of transitional arrangements was announced in 2010, however all national authorities have the freedom to customize the amended standards and transition periods as seen fit.

1.5.6 Focus points

With the numerous additions in the third version of Basel accords, this thesis objective is to focus on some of these subjects namely: the Fundamental Review of the Trading Book, the Counterparty Credit Risk and the incorporation of the Credit Valuation Adjustment capital requirement.

On one hand, the Fundamental Review of the trading book might be the most significant change that came across market risk since a while, adding several techniques and removing old practices with a special focus on sensitivities. On the other hand, counterparty credit risk was also addressed heavily in the new implementation after the crisis therefore a full look on the new standardized approach for the capital requirement was an appealing subject. Finally, a new addition was incorporated under the counterparty capital requirements which is the Credit valuation adjustment (CVA) for non-centrally cleared banks which is the case for Bank Audi. Being a part of the counterparty risk and having the most recent capital requirement methodology converging towards the FRTB, this was the third focus point of this thesis.

The Fundamental Review of the Trading Book

This new approach implemented in the Basel III framework highlights the weakness of previous Basel versions in handling market risk and presents a new set of techniques in order to reflect more precisely the market risk into the capital required.

As previously discussed, in a bank two main books are present: the banking book and the trading book. Grosso modo, all instruments held to maturity (long term) are held in the banking book whereas all tradable instruments are held in the trading book. Before the FRTB, no clear boundaries between these two books were set therefore due to some benefices in terms of capital requirement among them, banks used to 'easily' shift an instrument from one book to another. One main purpose of the FRTB was to set clear limitations on which instruments fit in the trading book and which do not. Another important change in the FRTB is the passage from the long-used Value at Risk to the expected shortfall concept. Plus sensitivities are now the base of the capital requirement computation method, noting that the sensitivity approach was not held earlier and is another pioneer implementation of the FRTB framework for the market risk.

The initial FRTB paper was published in 2013, after several consultative documents and comments, the finalized version came out in January 2016 with an announced due date for December 2019.

In the second chapter of this thesis, we discuss the FRTB in the trading book framework based on the December 2014 Basel Committee third consultative paper on outstanding issues related to this subject. Recognizing the significant operational burden posed by certain features of the proposed framework, including the revised standardized approach (cashflows needed) , several alternative treatments were tested in the 2014 QIS and will be further assessed through a follow-up QIS in early 2015. This document sets: the treatment of internal risk transfers of equity risk and interest rate risk between the banking book and the trading book, a sensitivities-based methodology in the revised standardized approach and a simpler method for incorporating the concept of liquidity horizons in the internal models approach

A previous consultative paper proposed a cash flow-based method which required banks to decompose financial instruments into their constituent cash flows and then discount each cash flow using the risk-free curve for each currency plus the credit spread of each instrument. Banks had many constraints and issues regarding this method (data wise), therefore following these concerns, the Committee agreed on a sensitivity-based approach (SBA) as an alternative to cash flow-based calculations for the standardized approach. This new method would require banks to use price and rate sensitivities that are more likely to be available in their systems as inputs into the different asset class treatments. The use of sensitivities thus reduces the implementation cost of the revised standardized approach.

The standardized approach capital requirement for the trading book is the sum of: The linear (delta and Vega) risk and curvature requirements for the general interest rate risk (GIRR) capital charge, Credit Spread Risk (non-securitisations), CSR (securitisation non-correlation trading portfolio), Equity capital charge, Commodity capital charge, FX risks and Additional requirements for default risk (non-securitizations), default risk (securitization non-correlation trading portfolio) and default risk (correlation trading portfolio). In Chapter 2, we are discussing the SBA for the GIRR in the trading book.

Counterparty Credit Risk SA-CCR

As noted previously, derivatives risk are primary held in the OTC traded derivatives. Moreover, the size of that market relatively to the exchanged-traded derivatives is much more important therefore much more subject to risks: A BIS survey (Semiannual OTC derivatives statistics at end-June 2012) shows that the notional amount outstanding for OTC derivatives totaled USD 639 trillion in June 2012, while the notional amount outstanding of derivatives traded on exchanges was USD 60 trillion.

The sub-prime crisis highlighted shortcomings in previously applied risk management rules for derivatives under the Basel II framework (cf. BSCBS (2006)), we will briefly cite the most impactful specifications:

- Wrong way risk is the risk of having an disadvantageous correlation between the exposure to a counterparty and its creditworthiness. This type of risk became clear during the crisis where defaults, deterioration and exposures went in the same trend: when a counterpart credit rating deteriorates, the exposure to it amplifies.
- Mark to market losses due to the credit valuation adjustments were not captured under the Basel II framework.

- The connection between different financial institutions was not taken into account: Basel II demanded the same correlation between financial and non-financial institutions whereas the crisis showed that the financial institutions are more correlated among each other by at least 25 % than the non-financial ones.
- Closeout periods were also miss-estimated because when there is a default or a deterioration the period will be a lot longer than the one specified.
- One last observation was the very-low margins put for transactions: initially at the start of any deal margins could be demanded however, the one demanded under Basel II were too low to be adequately compensating when a problem occurs.

The new Counteparty Credit Risk capital charge computation methodology, the Standardized Approach for CCR (SA-CCR), places banks at an interesting crossroads regarding a possible upgrade to their standardized or internal risk measurement and control policies. On first of January 2017, the Standardized Approach for Counterparty Credit Risk (SA-CCR) will take effect. This methodology replaces the Current Exposure Method (CEM) and standardized method (SM) implemented respectively in 1995 and 2005. SA-CCR is used for derivatives and SFTs improving the way hedging techniques are reflected in the capital charge computation.

In terms of capital requirement, the SA-CCR is more demanding then what preceded it. Per example, the capital charge of an un-margined 5 years interest rate swap was 0.5% under the CEM and now is a full 3.10% under the SA-CCR: an increase of 6.2 times is in place. In the margined case, the ratio is 186% (cf. FIS, 2016). We can clearly notice the impact induced by this approach.

One major addition was the reflection of the marginning agreements in the capital charge computation in the SA-CCR, a novelty not seen in previous techniques. A multiplier reflecting the level of collaterization is also in place, stressed calibration of the add-ons and optionnality consideration is added as well.

Credit Valuation Adjustment

After the financial crisis of 2007-2008, counterparty credit risk losses were thirdly caused by actual defaults and two-thirdly due to credit valuation adjustment. This raised many questions on the way of handling Credit Valuation Adjustment (CVA) in banks therefore Basel amended an additional capital charge for this risk aimed at improving banks' resilience against potential mark-to-market losses associated with deterioration in the creditworthiness of counterparties.

By exempting centrally cleared trades from the new capital requirement, Basel is pushing banks towards clearing their portfolios. However, in some countries, and under some circumstances, banks are not able to clear their trades therefore the capital charge should be computed taking into account the negatively impacting correlation between the market factors and the credit behaviors of the counterparties, also known under the name of Wrong Way Risk (WWR).

Basel proposed in 2015 a review of the CVA framework, after receiving comments at the end of this same year and guiding QIS on the subject, the most recent CVA related document published by Basel at the time of writing this thesis is the QIS entitled Instructions CVA QIS on February 2016. In this framework, two approaches were considered to compute the CVA capital charge a basic approach and a more complicated approach that converges towards the FRTB market risk framework.

The rationale behind these changes to the CVA framework are summarized by the BCBS as follows: to better capture all CVA risks and better recognize CVA hedging techniques, align industry practices (more specifically alignment with the IFRS 13 regulations) and finally alignment with the proposed changes in the market risk framework (FRTB).

1.5.7 Basel IV

Under current political changes, and financial reforms, discussions about the changing aspects of Basel III are being referred to as the Basel IV framework to notably show the important modifications in these regulations. Additions in capital requirements highlighted this shift. Capital output floors is the most discussed issue regarding Basel IV: Regulators are trying to define one common or multiple floors to be applied on internal models as determined by standardized approach: suggestions range from having internal models floored at 60% to 90% of the standardized approaches; however final calibration is still pending at the time of writing.

Other changes are observed: credit risk witnessed revised risk weights and additional requirements, operational risk has a new standardized approach, market risk has stricter rules and boundaries, additionally regarding CVA risk the internal-model based approach was abolished, the new approaches are either sensitivity based or enhanced in order to reflect the market conditions. A practical more complete summary of the Basel IV anticipated format could be found in PWC poster (cf. PwC, 2016).

Since the start of Basel regulations up until today, Basel gave a safer aspect to the banks and the financial markets after each new framework. Few doubted the possible achievements of this committee claiming that with each step further and each enlargement of the participating countries it would be more difficult to reach common agreements. This was proven to be wrong because a homogeneous approval on Basel III was reached far more quickly than the one reached on Basel II. However, the tension is true, the difficulties faced by Basel is here but for other reasons. With President Trump election and his goal of loosening the banking regulations in America, commitment to Basel rules is threatened (cf. Jones, 2016).

After spending almost nine years building a regulation that prevents the financial crisis from retaking place, fears are obvious on the continuity of this process. The problem now is more old-fashioned, between the US and them wanting to tighten controls on the internal models, and the much less riskier Eurozone countries that oppose this approach and the UK which is stuck in between after the Brexit. Making America great again is not likely to accept with open arms more Basel rules that restrict its activity and without the world's largest financial market supporting them, other countries might diverge from Basel rules too. In addition, Europe has its own problems now with the Brexit and the implications of such event on the European market. Several news articles are discussing these issues recently, we note namely: 'The Guardian' article's (cf. Davies, 2016). and Numerix's paper entitled 'Basel under Trump' (cf. Beckwith and Sharma, 2016).

The water sure seems to be strongly agitated now more than ever regarding regulations and implementations with the changing scenes worldwide and a common agreement would not be very easy to accomplish. All of this being said, if the commitment to international standards falls everyone will suffer: Countries will impose each its own regulations which will result in a less robust system and induce a financial crisis all over again, and that is a scenario that every one should be trying to avoid.

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Chapter 2

Analyzing and Comparing Basel's III Sensitivity Based Approach for the interest rate risk in the trading book

A bank' s capital charge computation is a widely discussed topic with new approaches emerging continuously. Each bank computes this figure using internal methodologies in order to reflect its capital adequacy; however, a more homogeneous model is recommended by the Basel committee to enable judging the situation of these financial institutions and relating different banks among each other.

In this paper, we compare different numerical and econometric models to the Sensitivity Based Approach (SBA) implemented by the Basel Committee on Banking Supervision (BCBS) under Basel III in its December 2014 (rev. March 2015) publication in order to compute the capital charge in the trading book. We study the influence of having several currencies and maturities within the portfolio and try to define the time horizon and confidence level implied by Basel's III approach through an application on bonds portfolios.

By implementing several approaches, we are able to find equivalent VaRs to the one computed by the SBA on a pre-defined confidence level (97.5 %). However, the time horizon differs according to the chosen methodology and ranges from 1 month up to 1 year.

Keywords: Capital charge, Sensitivity Based approach, Basel III, bonds portfolio, trading book, interest rate risk

2.1 Introduction

Commercial banks are a key component of today's financial and economic system. Banks allocate funds from depositors to borrowers, convert maturities, and provide financial products. These services among others enhances the efficiency of the overall economy. Given this crucial role, adequate regulations should apply to monitor banks risks.

Since its first issuance in 1988, Basel has been the main banking regulation authority initializing with some main credit risk rules. In 1996, the market amendment was issued setting the basic standards regarding trading assets and the value at risk computation methodology. It also divided the risk into market and credit risk; market risk being divided between equity, interest rate, foreign exchange, commodity, and option risk with a standardized capital computation approach treating each asset class separately. In 2006, Basel II came along with more 'personalised' approaches such as Internal Rating Based (IRB) for credit risk, internal models for Over The Counter (OTC) derivatives exposure along with the introduction of the operational risk charge.

However these regulations did not prevent major crisis hitting the international market causing huge losses in different sectors (cf. Baptistab et al., 2012). As a response to this shortage, Basel 2.5 was created beginning 2011 as a response adding more capital to the trading book (especially on the poorly modeled products). Basel 2.5 additions target the stressed VaR concept, the incremental risk charge and few new standard rules regarding the banking book.

In 2013, after a thorough observation of the consequences of the crisis and the attempt for correction made by 2.5, Basel III was introduced. The main functions of this issuance are: increasing capital for counterpart exposures, tightening the definition of the bank's capital, adding buffer for liquidity and introducing a new leverage ratio (cf. BCBS, 2013). In parallel, increasing the trading book capital requirement under Basel 2.5 was required following the crisis and was not well designed: the calculation remains non-risk sensitive and highly conservative, and differences in model approval persist between jurisdictions (cf. Babel, 2012)

As a result, in May 2012 the Basel Committee published a Consultative Paper on a 'Fundamental Review of the Trading Book' (FRTB) to improve this framework, then in December 2014, "Fundamental review of the trading book: outstanding issues", and its comments March 2015, the BCBS exposed the weaknesses of Basel's previous approaches and replied to frequently asked subjects (cf. BCBS, 2014 c). It suggested some major changes to the trading book to be implemented by 2018: scope and approval process (boundary of the trading book, desk level model approval, model testing, model independent assessment tool), modeling Issues (stressed expected shortfall, liquidity adjustments, diversification, default and migration risk, and non-modelable risk factors), and new standard rules for capital charges computation.

The standard rule suggested by the consultative document for the FRTB is based on sensitivities, hence it is called the "Sensitivity based approach" (SBA): it is suggested to be implemented as the 'homogeneous' method for capital charge computation across all banks. The SBA is based on percentages and correlations between different maturities and currencies (cf. BCBS, 2014 a). The existing standard rules poorly reflected hedging or diversification thus inflating the trading book capital level. The SBA is simple yet risk sensitive which is already a big improvement. SBA is a standardized method that reflects the risk resulting from: Interest rate, credit spread, equity, commodity, foreign exchange, options risk and default.

Comparing regulatory approaches, an obvious contrast between Basel and Solvency is noted: Solvency II has a similar three pillar structure as Basel's Accords. The capital requirements are described under the first pillar and refer to all types of risks: an insurance is exposed to: market risk (interest rate risks, equity risk, property risk, spread risk, concentration risk and currency risk) and counterpart default risk. Both frameworks take diversification effects into account and use square root formulas. However, these aggregation approaches are applied at different levels: a considerably stronger risk differentiation is shown under Basel III. For example, the SBA equity risk distinguishes 10 risk categories in order to assign the risk weights, in contrast to one single shock for all listed equities under Solvency II. Under the interest rate risk, SBA is Basel's III approach whereas in solvency II a shocked scenarios based computation sets the capital charge (cf. LAAS and Siegel, 2015).

Seemingly, the SBA has several add-ons regarding sensitivity and diversifying considerations however it still has some issues (specifying the coefficients) and details concerning the aggregations that need to be tweaked; for instance the figure under the square root is sometimes negative (cf. ISDA, 2015). In this dissertation, we aim to focus on the suggested standard rule by the FRTB in order to compare it with other econometric models to find an equivalent capital charge computation technique with few additional details such as time horizon and confidence level for a given capital. Among the different risk modulations, we chose to focus on the interpretation of the interest rate risk capital charge calculation.

According to Oxford Dictionary of Economics, interest rate is defined as "The charge made for the loan of financial capital expressed as a proportion of the loan". More formally, Basel Committee on Banking Supervision (cf. BCBS, 2004) indicated that interest rate risk (IRR) is the exposure of a bank's financial condition to adverse movements in interest rate.

The sound IRR management conducted by Basel Committee on Banking Supervision had been the source on which analysts rely to evaluate the activities of bank's risk management of interest rate (cf. BCBS (2004)). In the guideline, the committee offers four basic elements of IRR: appropriate board oversight, comprehensive internal controls, adequate policies and appropriate risk measure. The SBA falls under this forth element in modeling the interest rate risk in the trading book.

Our aim in this work is to understand the computation of the interest rate risk in banks based on BASEL's III approach. However, the SBA remains relatively vague and the choices of its coefficient and correlation parameters are not robustly detailed and documented. Hence, studying the interest rate risk from an econometric point of view in order to compare and contrast the results is critical and highly important.

Based on different central banks approaches for term structure interest rate, we selected few econometric models. The main idea was to reduce the dimensions of the database, study the dynamics of these 'reduced' factors and then conclude on the wider data range dynamic. We introduce the methods used to derive capital requirement and compare them with SBA's in order to conclude on some equivalence between them.

Having this objective in mind, the structure of the work is as follows: We started by modeling each interest rate curve on a stand-alone maturity basis using a Generalized Auto regressive Conditional Heteroskedasticity (GARCH) approach. It is worth noting that by doing so, we dropped a crucial information which is the strong correlation between these maturities, however we needed this phase as a starting point and a comparison threshold. Modeling the volatility of term structures using GARCH processes has become a current practice due to its numerous advantages relative to alternative models. GARCH-methods are a way of investigating how a function of past returns, in a specific financial series, should be constructed and mapped onto the second moment (cf. Hull, 2000). Proposed by Engle (1982) and then generalized by Bollerslev (1986), GARCH models explain high frequency financial data series through the auto regressive conditional heteroskedasticity and can model simultaneously conditional mean and conditional variance (cf. Edison and Liang, 1999). Two parameters for orders could be used in order to optimize the results of the tests regarding GARCH coefficients convergence. However, in practice, low orders are more frequently used. The first-order (p=q=1) GARCH model (cf. Taylor, 1986) has become the most popular GARCH model.

Secondly, we introduced the component approaches starting with the Principal Component Analysis (PCA) which is one of the multivariate analysis techniques usually used for correlation studies, data reduction and efficiency assessment (cf. Levieuge et al., 2010). This method incorporates the interdependence between term structures maturities: it considers the correlated curves and generates new non-correlated variables. Each factor is related to a loading and a cumulative variance defining the variance explained by each one of the new variables. PCA creates the same number of term structures included in the model however, we need to choose the reduced number of factors that we want to handle. In this work, we chose to cover 98% of the variance, by considering two or three factors. Using a GARCH model, we only project the chosen factors and not the loadings; then we re-create the entire data from the projected factors and previously observed loadings.

Thirdly, we introduced the implementation of the Independent Component Analysis (ICA): it provides a mechanism of decomposing a given signal into statistically independent components. PCA uses only second order statistical information however, ICA uses higher order (kurtosis) for separating the signals which permits more conclusive results in financial data (cf. Comon, 1994). A drawback in the ICA is its inability to indicate the data variance coverage for each factor, therefore the modeler has to define the number of factors to be considered; in this dissertation we chose to include three ICA factors.

Regarding the last approach, a factor model is suggested: the Dynamic Nelson Siegel. No GARCH processes are used, instead a mix of Nelson Siegel estimation and Autoregressive Integrated Moving Average (ARIMA) processes projection are put in practice. Yield curve factor models, such as Nelson-Siegel (1988), its dynamic version (cf. Diebold and Li, 2006) and its arbitrage-free counterpart proposed by Christensen, Diebold and Rudebusch (2011), have been extensively applied to forecast bond yields. We used the Dynamic Nelson Siegel due to its flexibility in representation especially for the long term projection. By fitting the curves, projecting the factors using Diebold method and the loadings employing an ARIMA process, we are able to reconstruct the curves from which we concluded the capital requirement.

The capital charge using the previously mentioned methods can be computed on a certain confidence level basis and for a given time horizon; therefore comparing these methods to SBA would determine a common time horizon and confidence level, reaching the purpose of this work. We start by explaining in details the procedure of the SBA, the correlation between the duration of the portfolios and the capital charge required by this procedure then compare the methods using different approaches. These latter will be based on bonds portfolios denoted in: euros, dollars and Turkish lira from the French, German, US and Turkish governments yields respectively, for maturities between 1 month and 30 years.

In this paper we proceed as follows: in Section 2 we provide a detailed description of the sensitivity based approach through hypothetical portfolios, we also show the link between this capital charge computation and the portfolios duration. In section 3, we proceed with an overview of four different approaches then we explain how we computed the capital charge using these processes. In section 4 we present the empirical analysis, describe the data, estimate the models, compute the VaRs and conclude with analyzing, comparing and back-testing the capital requirement calculations. In section 5 we offer some interpretation and conclusive remarks.

2.2 Sensitivity Based approach (SBA)

2.2.1 Introducing the approach

This new method would require banks to use prices and rate sensitivities in order to compute their capital charge. This revised (sensitivity-based) standardized approach would capture more granular or complex risk factors across different asset classes in the trading book (cf. BCBS, 2014 a). It builds on the standardized framework tested in the trading book QIS conducted in the second half of 2014 (cf. Basel, 2014 b). This remains a consultative document that could be changed in future times.

The proposed methodology covers the delta and optionality risk: general interest rate risk, credit spread risk of non-securitization and securitization exposures, equity, commodity and FX risk. Vega and curvature risk measurements are under development in order to measure the sensitivity of the value of an option with respect to a modification in volatility and the rate of change of delta.

2.2.2 Implementation reasons

- The approach must provide a method for calculating capital requirements for banks with a level of trading activity that does not require sophisticated measurement of market risk.
- It provides a fall back in the event that a bank′s internal model is deemed inadequate, including the potential use as add-on or floor to an internal model-based charge.
- The approach should facilitate consistent and comparable reporting of market risk across banks and jurisdictions.

2.2.3 Compare and Contrast Value At Risk and Expected Shortfall

Since 1996, the Basel Committee has proposed to use the Value-at-Risk (VaR) as an easy to grasp extreme event measure with a certain confidence level. However, better measures of risk are desired for an extra robust risk management such as the expected shortfall.

While Basel II was considering a VaR approach, Basel 2.5 and 3 rejected this method due to several arguments dismissing it as inaccurate in favor of the tailed VaR or, as more commonly known, the expected shortfall. In practice many evidences could question both methods and many evidences could support each.

Comparing these two risk measures we note the following:

- The Value at risk can be misleading: it is seen as 'the maximum loss' therefore it is giving a false sense of security, whilst it is real signification is the threshold of losses in the chosen confidence level meaning that the loss will exceed this VaR, without noting the amount of this excess, the ES covers this shortage.

- ES has better theoretical properties than VaR. If two portfolios are combined, the total ES usually decreases -reflecting the benefits of diversification- and certainly never increases. By contrast, the total VaR can and in practice occasionally does increase: VaR is said to be not coherent because it does not have this particular property.
- The expected shortfall has its shortcomings against the VaR too: First, it is difficult to back-test. A key point is that back-testing a stressed model, whether VaR or ES, is not possible because we are interested in whether the model performs well for another stressed period, but we do not have another such period to use for testing.
- Another disadvantage of ES is that estimates of the measure may not be as accurate as estimates of VaR. The accuracy of VaR and ES is about the same when the loss is normally distributed, but that VaR estimates are more accurate than ES estimates when the losses have fat tails. This means capital calculated from ES may be less stable than capital calculated from VaR.

The knowledge of relationship between different risk measures is important for selecting appropriate risk control strategies.

- On the first hand, for a given risk level p, the ES can be derived by multiplying the VaR with an amplifying factor. In their paper Sensitivity Analysis of Distortion Risk Measures, Gourieroux and Liu (2006), show that this amplifying factor is mostly a function of p and only independent of p if the underlying distribution is Pareto.

- On the other hand, this same publication, proves that the VaR and Tail-VaR can be related through their risk levels by some transformation that could be linear or not.

For parametric distributions several tests and modeling can be made in order to contrast and compare ES and VaR and find the link between these two measures however, in other 'real' situations and dynamic portfolios such approaches are not that easy due to the difficulty of estimating the ES. In this work, we compare the Basel III approach to our models: Basel III leans on an expected shortfall approach whereas we use the value at risk tool. Equivalences will show the convergence between these methods on differing confidence level and time horizons.

2.2.4 Computational steps

We first compute the net sensitivity of the bond (relative 1 bps change) and multiply it by its corresponding risk weight in order to get the weighted sensitivity. We note that for each maturity a different risk weight is allocated based on a matrix provided by the Basel committee. For each currency, the 'average' is computed as the square root of the sum of squared single weighted sensitivities and double products of these latter weighted by given, maturity based, correlation coefficients. Aggregation on a portfolio level is another sum of the squared capital charges computed for each currency plus the double products weighted by a factor of 0.5 fixed by Basel. The method is as follows:

1. Get the observed yield and price on the market.
2. Compute the net sensitivity of each instrument and recalculate the price.
3. Based on two choices given by Basel, following the banks preference, get the weighted sensitivities (WS), i and j refer to the maturity: we notice an decreasing trend in weights i.e. for short maturities high volatility is implied therefore higher risk weights are implemented rather than the relatively low weights for the more stable, longer maturities.
4. Form buckets by sorting each currency in a separate bucket.
5. For each bucket compute the following using the correlations coefficients given by Basel.

$$K_{bucket} = \sqrt{\sum_{i=1}^{N} WS_i^2 + \sum_{i=1}^{N} \sum_{j \neq i} \rho_{ij} WS_i WS_j}$$

ρ represents the correlation between the weighted sensitivities for products that have the same behavior vis a vis a market risk: for short maturities the correlation is tight between 'near' maturing products. However, this correlation parameter decreases slightly in med-term conditions to rise again and become a full 100% correlation among the 15 years instruments and above.

6. Compute the capital charge (having M buckets:

$$\text{Capital Charge} = \sqrt{\sum_{l=1}^{M} K_i^2 + 0.5\sum_{i=1}^{M}\sum_{p\neq l} S_p * S_l} \text{ where } S_l = \sum_{d=1}^{l} WS_d \text{ for all maturities in bucket } l.$$

2.2.5 Hypothetical example

Let us consider a hypothetical portfolio composed of only one zero coupon bond. The portfolio is studied on a rolling basis and the bond does not include optionality. In this work, we do not consider the effect of currency or default risk.

Table 2.1: One Zero coupon SBA capital charge

Price	$P = 100e^{-r_T T}$
Modified price	$P' = 100e^{-r_T T - 0.0001T}$
Sensitivity	$S = \frac{P'-P}{0.0001}$
Weighed sensitivity	$WS = RW \times S$
Capital Charge	$\frac{WS}{P}$

The previous example proves that the capital charge under the SBA is only dependent of the zero bond maturity (therefore duration) and the associated risk weight of this particular maturity.

We analyzed the three following cases: a portfolio consisting of one bond, two same currency bonds and different currencies bond in order to come up with one generalized approach. Step by step computation and numerical examples can be found in ***Appendix 2.1***.

Hereafter we consider a portfolio combining three bonds: two in a same currency and a third in a different one, we obtain the following:

Let α_1 denote the first currency and α_2 the second one, P_1,P_2 the price of the two bonds in α_1 and P_3 the bond in α_2; τ_1,τ_2 and τ_3 their respective maturities.

- For $i \in 1,2,3$ and $t_i \in 0,...,\tau_i$,the prices and durations are shown as follows: $P_i = \sum C_{it}e^{-r_{it}t}$ and $D_i = \frac{\sum tC_{it}e^{-r_{it}t}}{P_i}$ with C_{it} being the cashflows and r_{it} the interest rate for bond i at time t.
- We compute the net sensitivity NS_i and the weighted sensitivity WS_i:
  $NS_i = \frac{\sum_t C_{it}e^{-r_{it}t} - \sum_t C_{it}e^{(-r_{it}-0.01\%)t}}{0.0001}$ and
  $WS_i = \frac{RW_i}{0.0001}\sum_t C_{it}e^{-r_{it}t}(1-e^{-0.0001t}) = RW_i * D_i * P_i$.
- Having two different currencies, two buckets are created and a K_{α_i} is computed for each:
  $K_{\alpha_1} = \sqrt{WS_1^2 + WS_2^2 + 2\rho_{12}WS_1WS_2}$, in the second bucket having only one bond $K_{\alpha_2} = WS_3$
- Bringing these together, SBA demands a 0.5 coefficient for the correlation and a sum of square to compute the capital charge:
  $CC = \frac{\sum_{i=1}^{3} RW_i^2 P_i^2 D_i^2}{\sum_{i=1}^{3} P_i}(1 + \frac{2\rho_{1,2}RW_1D_1P_1RW_2D_2P_2 + RW_1D_1P_1RW_3D_3P_3 + RW_2D_2P_2RW_3D_3P_3}{2(\sum_{i=1}^{3} RW_i^2 D_i^2 P_i^2)})$.

2.3 Equivalent interest rate risk assessment methods

Computing the capital charge of a given portfolio needs the computation of the value at risk using the traditional approaches. Therefore, we will compute the value at risk combining different known methods in order to compare them with the SBA results.

2.3.1 GARCH(p,q) model specification

ARCH methods were introduced by Engle in 1982 then generalized by Bollerslev in 1986 (cf. Bollerslev (1986, 2008)) as a conditional variance prediction model, especially useful when the volatility of the financial data is the main issue.

Let X_t denote a real-time stochastic process and σ_t its conditional variance; GARCH (p, q) process is given by:

$$X_t \mid \sigma_t \sim N(0, \sigma \mid t^2)$$
$$\sigma_t^2 = \alpha_0 + \sum_{i=1}^{p} \alpha_i X_{t-i}^2 + \sum_{j=1}^{q} \beta_j \sigma_{t-j}$$

Where $p \geq 0, q \geq 0, \alpha_0 \geq 0, \alpha_i \geq 0$ and $\beta_j \geq 0 \ \ \forall i, j$.

The GARCH approach has been used in modeling financial time series, test financial theories and interpret key features of a given data in a time-dependent matter.

In our bonds portfolio we consider government yield curves with maturities ranging from 3 months to 30 years, compute the return and apply GARCH models for each maturity.

The orders of a GARCH process play a major role in determining the results: q can be based on model selection tests such as the auto correlation function of the squared residuals; however with large q, estimation error might increase. Finding both p and q parameters can be facilitated through time series testing.

In our work GARCH models are determined on the basis of coefficients significance and Jarque Berra test (cf. Bollerslev, 2008): skewness and kurtosis are used for constructing Jarque Berra's test statistic to find whether the coefficients of skewness and excess kurtosis are jointly null (cf. Jarque and Bera, 1981).

When estimating GARCH models, computer-based softwares have to be used. Different softwares have different functionalities, drawbacks and features. Several works present these GARCH estimating software packages and compare them (cf. Brooks et al., 2003). In our work, the 'tseries' R-package is used to estimate these models.

We start by estimating the GARCH process for each maturity, after having adequately selected the parameters. Since the projection requires initial values for each yield curve, we adopted the traditional way of having the last observed yield as the first data point of projection and the volatility as the historically observed volatility for each curve. We project for one year, fixing a year as 252 days, using Monte Carlo simulations then extract the value at risk for different confidence levels from 95% to 99.9 %. The capital charge percentage was computed on a mean relative figure basis, i.e. the mean of all simulations is extracted of the VaR and divided again by the mean (10,000 simulations were in order).

2.3.2 PCA-GARCH

The principal component method summarizes the numerous factors affecting a system by a few uncorrelated variables, called principal components, which provide a description of the systems dynamics.

Principal component analysis is a process used to reduce the dimension of the data (cf. Jackson, 1991): This is useful in extracting a visual representation i.e. by reducing the considered dimensions to a much more compact ones enabling the researcher to represent visually the points. PCA transforms a number of starting points to a much reduced one using optimization criteria. Used criteria might be, among others, minimization of the mean-square error in data compression or finding mutually orthogonal directions in the data explaining a maximal variance.

This reduction in dimensionality is particularly useful in finance, since asset prices are affected by thousands of economic variables that are difficult to translate into a rigorous price model therefore this technique is commonly applied in banks to interest rate markets to describe the yield curves behavior to be used for scenario analysis and risk estimation.

The benenefits of PCA may be divided into: risk estimation, risk reporting and scenario analysis. This method allow a new representation of the same data however with a much more compact distribution that retains the same characteristics. It helps understanding the dynamics and the shifts of the curves. The chosen model has to explain at least 95% of the variation and include the fewest components possible. For factor analysis to be efficient, it is important that an appropriate sample size should be used.

To apply the principal component analysis, p vectors representing the weights or loadings will be considered such as: $w_k = (w_1, ..., w_p)_k$. These latters map each row vector x_i of X to a new vector of principal component scores $t_i = (t_1, ..., t_p)_i$, given by $t_{k_i} = x_i.w_k$.

Therefore instead of having 15 yield curves with different maturities, using the PCA process we reduce it to a number of principle factors that represent more than 98% of our data. Having these factors (in most cases 2 or 3) we project them on a one year basis using GARCH models and choose their parameters based on the previously mentioned details. After rebuilding the fifteen maturities using the projected factors and the previously computed loadings, we generate the VaR and capital charge of our portfolios using the same way selected in the previous methodology for the capital charge computation. This process adds the correlation between different maturities and shows the interdependency between all tenors even when the portfolio does not include the entirety of maturities.

2.3.3 ICA-GARCH

Independent components analysis, (cf. Comon, 1994), is another method to reduce dimensions that has the same functionality as PCA except for the difference in the determination of the components and the loadings: In PCA, the aim is to find vectors that best explain the variance of the data whereas in ICA the kurtosis is in focus. The latent variables are assumed non-Gaussian and mutually independent(cf. Bugli, 2007 and Burgos, 2013). ICA could be used in different fields such as digital imaging, stocks databases, economic indicators, geologic measurements or psychometric indicators. Initially, the process was mostly used to 'un-mix' several signals: different waves recorded at the same time, two time series interfering for a certain process, underwater signals...(cf. Amari, 1996 and Bell, 1995).

ICA is a data processing technique that aims to transform a certain set of data to another reduced, linear functions of statistically independent component variables:
Having an $m-$dimensional vector $x_t = (x_{1t}, x_{2t}, ..., x_{mt})$, using the ICA method we generate a matrix A and another set of vector s_t verifying the following:

$$x_t = A * s_t.$$

Having A is a $m * n$ matrix with elements that explains the effect (weight) of s_t on our original data x_t, and s_t a $n-$vector with mutually independent components.

Again this model includes correlation as well as GARCH estimations however it is an add-on to the previous method due to the following: ICA does not assume the non-correlation of the factors instead it supposes the independence, such that the normality of the data is not a must; on the contrary, non-Gaussian factors have an added-value. In this work ICA method follows the same process as PCA's: ICA to the full data panel, GARCH projection, rebuilding of the data, determining the VaR, capital requirement computation.

PCA and ICA differences are largely discussed in the literature(cf. Bugli, 2007 and Burgos, 2013): Both methods are given multivariate measurements with the purpose of finding a smaller set of variables with less redundancy, which would best represent the data. However, in PCA the tool do to so is by measuring the correlations between data elements, while in ICA the concept of independence is used, and the number of 'reduced ' variables is given less emphasis (cf. Hyvarinen et al., 2001). The earliest ICA algorithm that we are aware of and one which generated much interest in the field is that proposed by (cf. Herault and Jutten, 1986). Since then, various approaches have been proposed in the literature to implement ICA. These include: minimizing higher order moments or higher order cumulants (cf. Cardoso and Souloumiac, 1993), minimization of mutual information of the outputs or maximization of the output entropy (cf. Bell and Sejnowski, 1995), minimization of the Kullback-Leibler divergence between the joint and the product of the marginal distributions of the outputs (cf. Amari et al., 1996). This work is applied using the fastICA algorithm implemented in a R-pakage (cf. Delac et al., 2006).

Nelson Siegel method

The interest rate curve is essential for pricing, hedging and evaluating a portfolio. Various curve fitting spline methods have been introduced such as quadratic and cubic splines, exponential splines, B splines ... However, these methods were criticized for not being too representative of the economic situations. Therefore, Nelson and Siegel (1987) and Svensson (1994, 1996) suggested parametric curves that are flexible enough to describe the large frame of the financial conditions in a static method overview.

Nelson Siegel method consists of estimating three parameters using the maximum likelihood process or OLS to rebuild the yield curve (cf. Siegel and Nelson, 1988): the three Nelson-Siegel components have a clear interpretation as short, medium and long-term components. These labels are the result of each element's contribution to the yield curve.

$$y(\tau) = \beta_1 + \beta_2 \frac{1-e^{-\lambda\tau}}{\lambda\tau} + \beta_3 \frac{1-e^{-\lambda\tau}}{\lambda\tau - e^{-\lambda\tau}}$$

Where $\beta_1 > 0$, $\beta_1 + \beta_2 > 0$ and $\lambda > 0$ The Nelson Siegel model is extensively used by central banks and monetary policy makers (ex: Bank of International Settlements (2005), European Central Bank (2008)).

Dynamic Nelson Siegel

As a development to the traditional fitting approach, Diebold and Li (2006) introduce the Dynamic Nelson-Siegel (DNS) model by estimating the classical formula with time-varying factors and model them using autoregressive specifications projecting therefore the yield curves by adding dynamism to the parameters. Diebold and Li (2006) interpret β_{1t}, β_{2t} and β_{3t} as the slope, curvature and level of the curve. This method shows very encouraging results especially on a long time horizon.

$$y_t(\tau) = \beta_{1t} + \beta_{2t} \frac{1-e^{-\lambda_t\tau}}{\lambda_t\tau} + \beta_{3t} \frac{1-e^{-\lambda_t\tau}}{\lambda_t\tau - e^{-\lambda_t\tau}}.$$

Our chosen approach in this work is to fit the yield curves using the traditional Nelson Siegel and to project it afterwards: estimating the different yields using the Nelson Siegel function in R, R-package: YieldCurve, projecting the betas computed using adequate ARIMA processes (based on best-fit approach); maintaining the loadings as calculated historically, rebuilding the projected yields based on Diebold and Li's dynamic approach. Having the projected yields, a new portfolio evaluating could be placed, a value at risk and therefore a capital charge is computed.

Lambda: The lambda factor in the Nelson Siegel formula, as provided by Nelson and Siegel (1987), does not have any exact economic meaning. In fact, from the econometric point of view, it is a constant assuring a specific slope of yield curve. In practice, higher values produce a faster decay of yield curve and vice versa. In conclusion, the factor plays a key role especially in fitting the longer end of yield curves.

Nelson and Siegel (1987) fixed λ to simplify the computation allowing usage of the simple and linear ordinary least squares. Diebold and Li (2006) follow the same logic of exogenously predetermined λ however they suggested interpretation for the parameters as the slope, curvature and level. Based on such assumptions, and interpreting lambda as the maturity at which the loading on the curvature factor achieves its maximum, maximizing this loading would result in a numeric value for this coefficient: 0.0609.

Alternatively, in the related literature, Diebold et al. (2006) instead use the value of 0.077. Adding to that, other papers suggest different approaches for computing lambda not related to the aforementioned interpretation (cf. Gilli *et al.*, 2012). In this paper, lambda of the projected yield is also considered as a constant chosen as the mean of the previously estimated lambdas for each specific yield.

2.4 Application: bonds portfolios

2.4.1 Data used

The data is fetched from Bloomberg: Government yield curves 3 months up till 30 years maturities on a daily basis for: France, Germany, USA and Turkey. We chose to go with this selection in order to cover a heterogeneous sample having three different market conditions: two European stable markets, the American market and an emerging case such as Turkey. For each country, different dates are available, France data starts on 04/30/1998, German on 10/04/1991, US on 11/24/2003 and Turkey on 04/01/2005; all the data ending point is on 05/15/2015. The general statistics of these data points could be found in **Appendix 2.2** and all models' details in the **Supplementary Material** document.

2.4.2 Portfolios' duration and different capital charge requirements

In order to compare these methods, we build portfolios using either one unique currency or multiple currencies. The following plots represent the different yields for each currency:

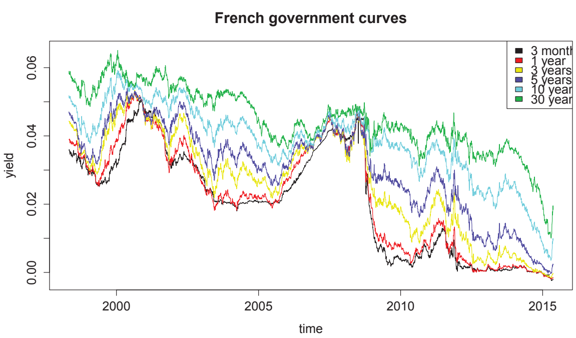


Figure 2.1: FRANCE government yield curves

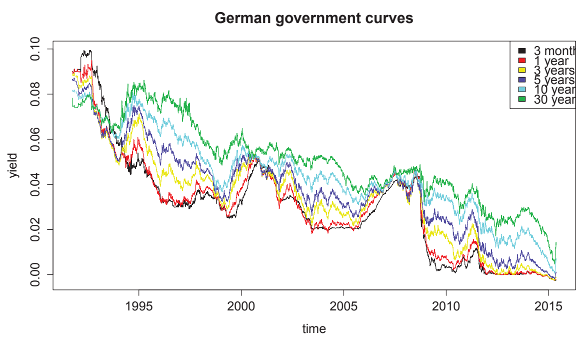


Figure 2.2: GERMANY gvt yield curves

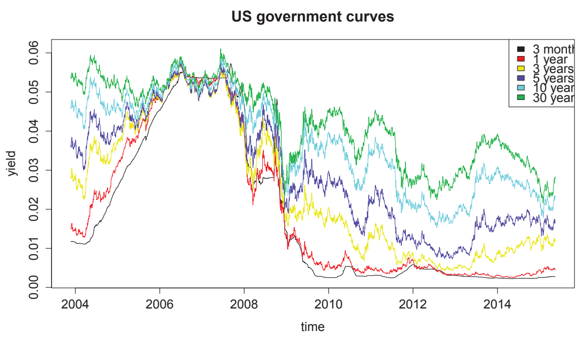


Figure 2.3: US government yield curves

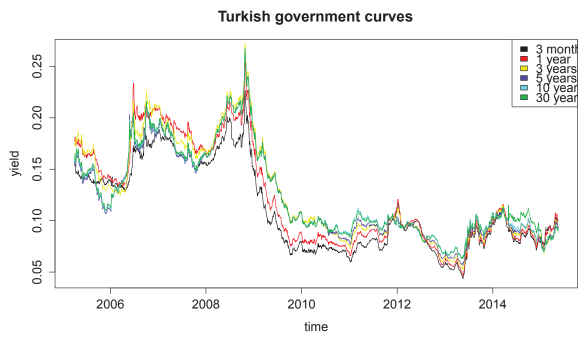


Figure 2.4: TRY government yield curves

In these plots we can distinguish four phases:

1. The normal phase up until 2004.
2. The moderation phase as called by Basel between 2004 and 2007, ending with the beginning of the financial crisis (low volatility).
3. The liquidity crisis between 2007 and 2008.
4. The zero bound phase where the volatility decreases going from 2008 up till the end of the sample: low short term volatility, high long term volatility.

2.4.3 Single currency portfolios

We consider four portfolios: for each governmental yield, with the same composition, consisting of 12 zero coupon bonds denominated in the local currency each consisting of: 3 one year ZC, 3 two years ZC, 2 three years ZC, 1 five years ZC, 1 ten years ZC and 2 fifteen years ZC.

Sensitivity Based Approach

SBA capital requirement is compared below to the portfolio′s duration at every date:

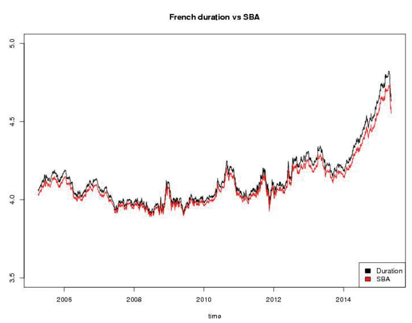


Figure 2.5: French duration vs SBA

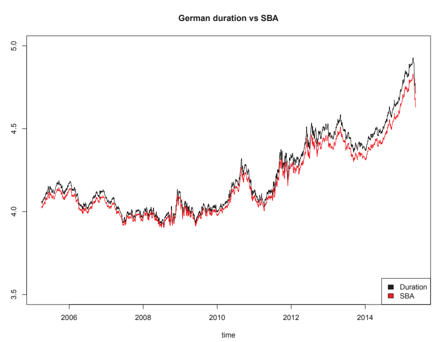


Figure 2.6: German duration vs SBA

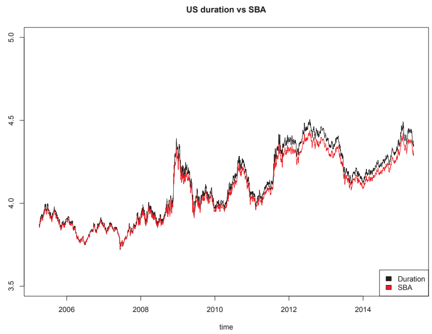


Figure 2.7: US duration vs SBA

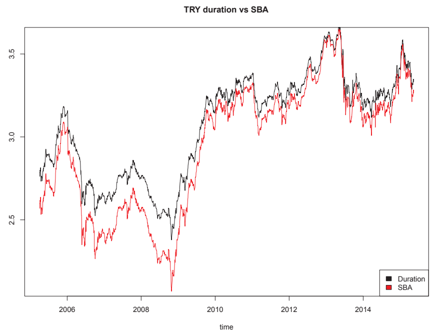


Figure 2.8: Turkish duration vs SBA

As previously shown by the three cases equations, the plots above reflect the correlation between the duration of the four chosen portfolios and the capital requirement computed using the SBA method.

It is clear that the coefficient depends on a certain factor reflected by the risk weight used. Having the same portfolio composition, the factor between the duration and the capital charge is the same. After noting the obvious resemblance between the behavior of the SBA capital requirement and the duration of these single currency portfolios, we proceed in applying the main goal of this paper.

Our aim is to define an equivalent to the SBA capital requirement using a VaR on a given confidence level and time horizon; we proceed as follows: For each chosen methodology, we compute the VaR of the portfolios price (Monte-Carlo simulations basis) and compare these VaRs to the SBA requirement; the interception between these figures will simulate the confidence level and time horizon equivalent to Basel's requirement. We initiate this comparative work by computing the GARCH process value at risk.

Please note that in the following plots red represent the SBA capital charge, black a 99.8 % confidence level, green a 99%, blue the 97.5% and magenta a 95 % confidence level. The term *CC* is used to design the capital charge.

GARCH model

For each currency, we have 15 yield curves with different maturities; we compute: $\Delta i_t = i_t - i_{t-1}$. Building on these differences, we estimate them using an GARCH model; projecting this model one year ahead (252 days) we build our 'future' portfolios. Repeating this process 10000 times, based on a Monte Carlo logic, we conclude the VaR and therefore the capital charge. Note that for all methods the SBA capital charge is computed as a percentage of the initial portfolio, in the other methods capital charge is computed as the relative change between the projected mean and values at risk of the initial portfolio value.

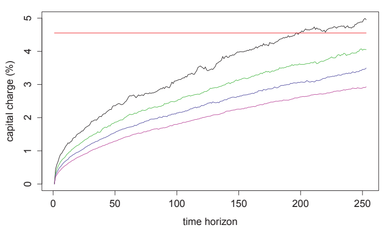


Figure 2.9: French GARCH CC

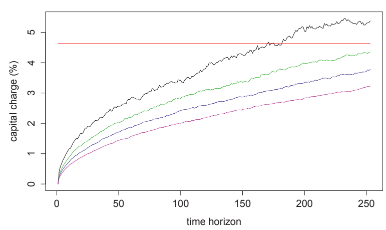


Figure 2.10: German GARCH CC

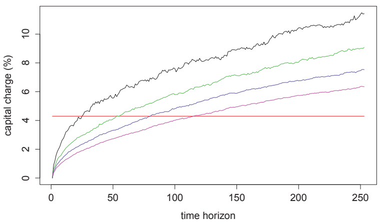


Figure 2.11: US GARCH CC

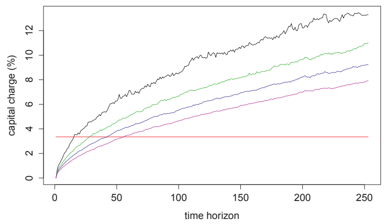


Figure 2.12: Turkish GARCH CC

Not accounting for the inter-correlation in our GARCH approach, the capital charge is expected to fall mostly below the SBA approach. We can observe the resemblance between the French, German and US market, however a very unstable behavior in the Turkish data: Turkey is located in a very fragile environment quickly influenced by numerous factors making its currency volatile.

PCA-GARCH model

Applying the PCA on the 15 maturities of each currency, we reduce the data into two components covering at least 98 % of the data. We project the first differential of these components using an adequate GARCH model then rebuild the entire maturities using the projected factors and the previously computed loadings. Monte Carlo simulations permits the extraction of the VaR at different levels and the capital charge.

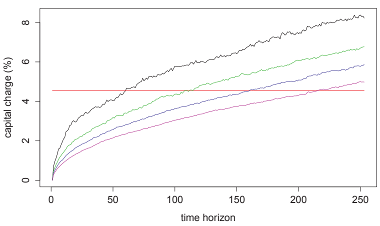


Figure 2.13: French PCA CC

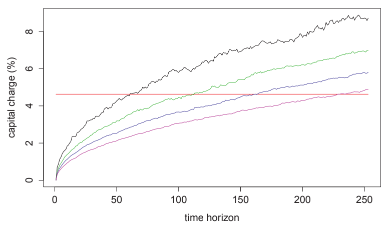


Figure 2.14: German PCA CC

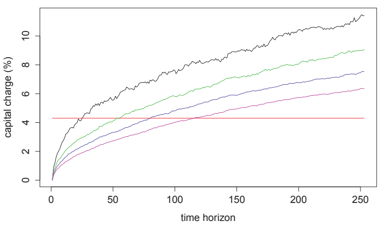


Figure 2.15: US PCA CC

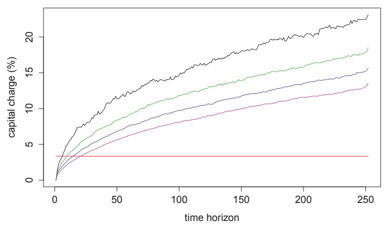


Figure 2.16: Turkish PCA CC

Once again EU and US data show the same behavior, whereas the Turkish data being very volatile shows different results (emerging market status). Quickly comparing GARCH and PCA, a clear increase in the required capital is showing in the PCA figures due to the incorporation of the inter-maturities correlation.

ICA-GARCH model

This method is similar to the PCA, but instead of using the principal components approach we used the independent components approach to increase the precision and reduce the assumptions.

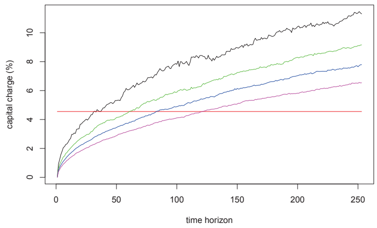


Figure 2.17: French ICA CC

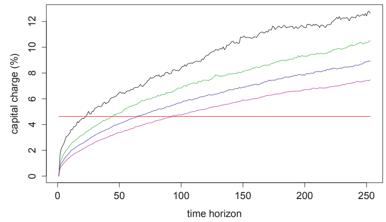


Figure 2.18: German ICA CC

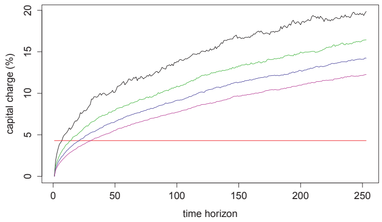


Figure 2.19: US ICA CC

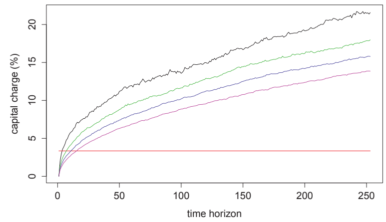


Figure 2.20: Turkish ICA CC

DNS-ARIMA model

After estimating the curves using NS model, we projected the beta parameters using the best fitted ARIMA(p,d,q) process. Along with the mean of the historically observed lambda's and the projected beta's, we rebuild the curves, estimate the VaR and capital charge.

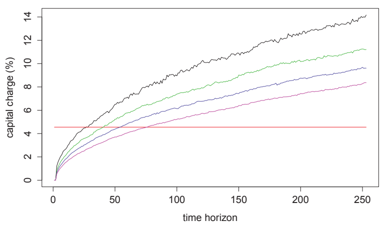


Figure 2.21: French DNS CC

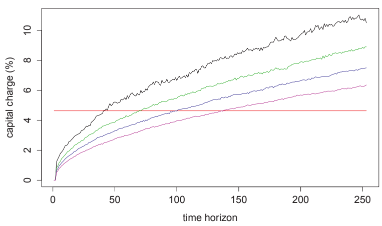


Figure 2.22: German DNS CC

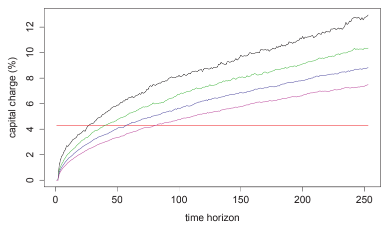


Figure 2.23: US DNS CC

The results show a quicker convergence in this method. However, in an unstable market such as the Turkish case, we do not observe any convergence in the Nelson Siegel parameter, therefore no projection could be applied.

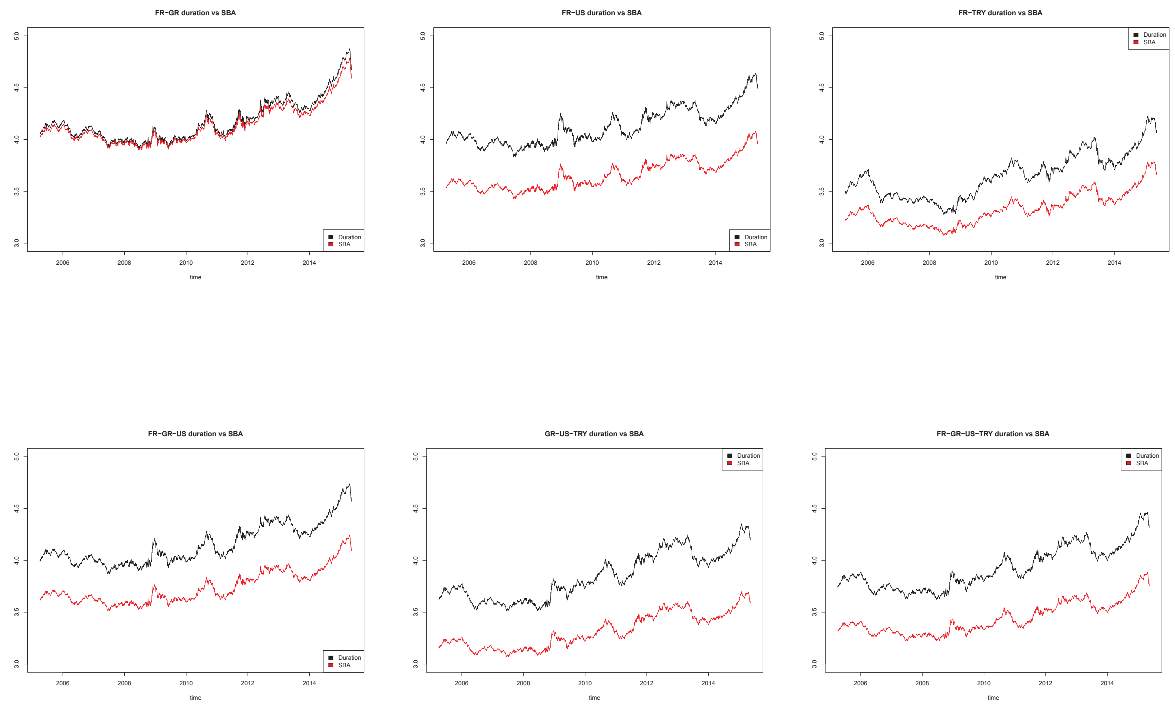
2.4.4 Multiple currencies portfolios

Denoting the previous portfolios by their government yield we have: $Port_{FRANCE}$, $Port_{GERMANY}$, $Port_{US}$ and $Port_{TURKEY}$.

In this section we consider multiple currencies combining the previously mentioned portfolios: $Port_{FR,GR}$, $Port_{FR,US}$, $Port_{FR,TRY}$, $Port_{FR,GR,US}$, $Port_{GR,US,TRY}$ and $Port_{FR,GR,US,TRY}$.

Sensitivity Based Approach

In this section, having multiple currencies, the correlation parameters between different curves at different tenors will be added. Note that both France and Germany are held in euros therefore they are part of the same bucket.



Similar remarks could be presented here regarding the parallel movement of the duration and capital requirement of these portfolios. This could be interpreted using the equations in the third case of **Appendix 2.1**.

Different portfolios capital charge

FR-GR portfolio

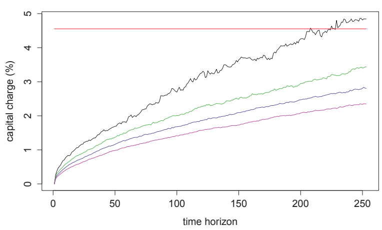


Figure 2.24: GARCH capital charge

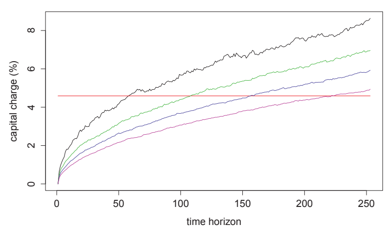


Figure 2.25: PCA capital charge

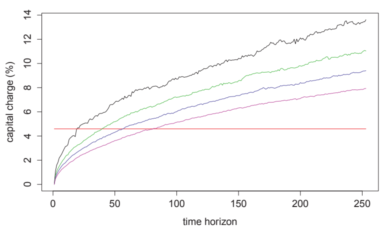


Figure 2.26: ICA capital charge

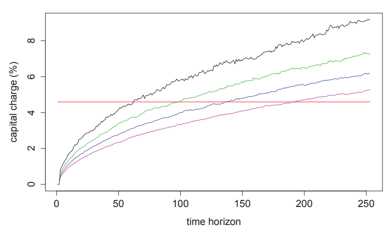


Figure 2.27: DNS capital charge

FR-US portfolio

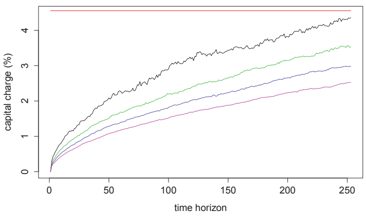


Figure 2.28: GARCH capital charge

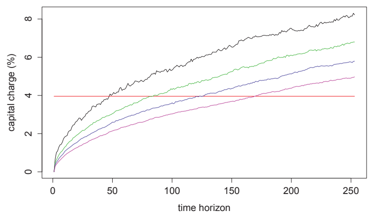


Figure 2.29: PCA capital charge

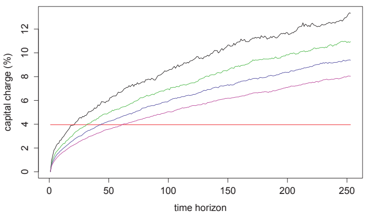


Figure 2.30: ICA capital charge

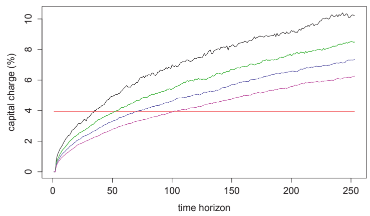


Figure 2.31: DNS capital charge

FR-TRY portfolio

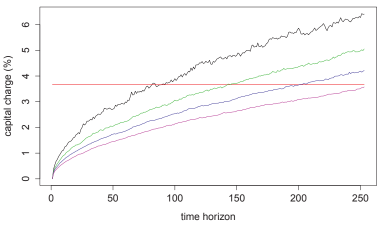


Figure 2.32: GARCH CC

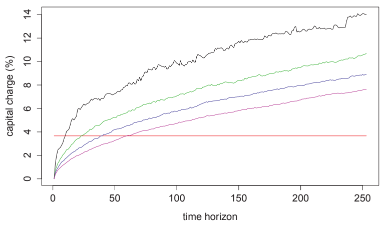


Figure 2.33: PCA CC

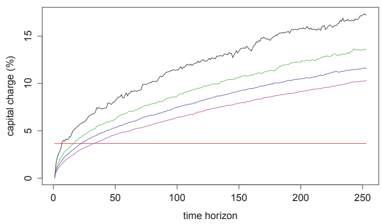


Figure 2.34: ICA CC

FR-GR-US portfolio

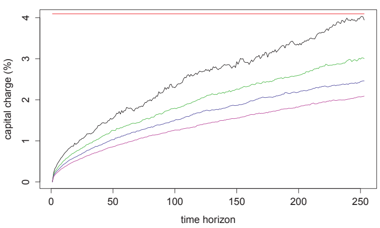


Figure 2.35: GARCH CC

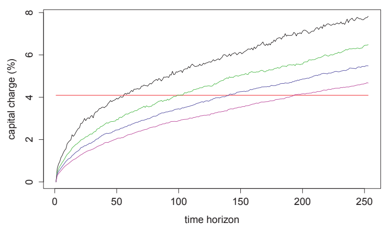


Figure 2.36: PCA CC

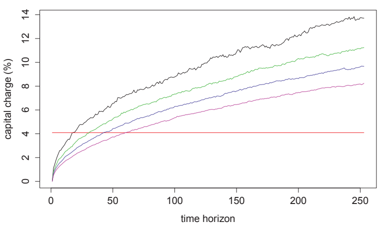


Figure 2.37: ICA CC

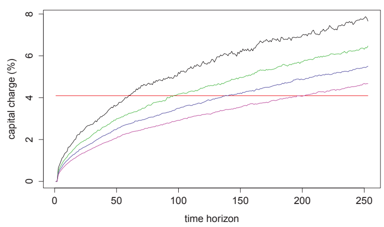


Figure 2.38: DNS CC

GR-US-TRY portfolio

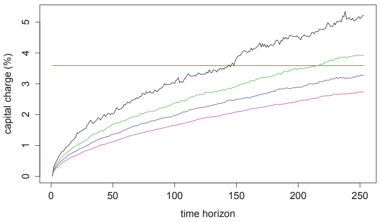


Figure 2.39: GARCH CC

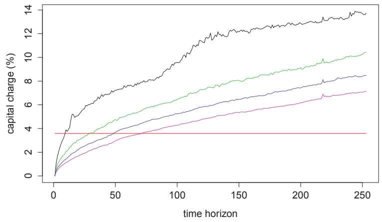


Figure 2.40: PCA CC

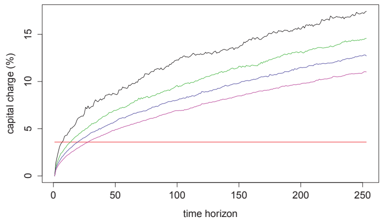


Figure 2.41: ICA CC

FR-GR-US-TRY portfolio

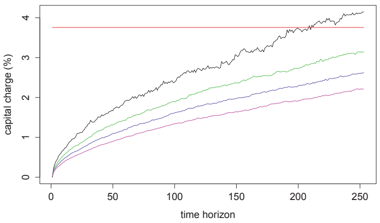


Figure 2.42: GARCH CC

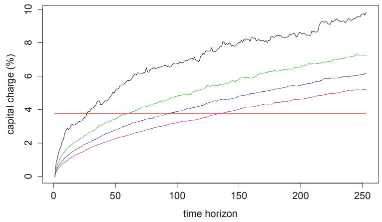


Figure 2.43: PCA CC

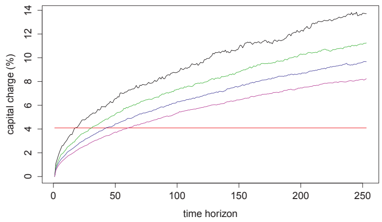


Figure 2.44: ICA CC

2.4.5 Comparing results

In order to reduce the fluctuation, the results were interpolated to a logarithmic function. Based on the single currency portfolios, GARCH model shows a permanent 'low' level of capital requirement compared to Basel and the other methods. This could be explained by the correlations' exclusion between different tenors in this first method. PCA and ICA methods show a close trend however, the ICA approach is more conservative and demands higher requirements. In all portfolios, DNS converges very rapidly, equaling the SBA on a short time horizon.
The following table summarizes the encountering points (in days) between the SBA and the different other methodologies studied for the ten portfolios.

Table 2.2: Encounter days with the SBA capital requirement

	GARCH			**PCA**			**ICA**			**DNS**		
	95%	**97.5%**	**99%**	**95%**	**97.5%**	**99%**	**95%**	**97.5%**	**99%**	**95%**	**97.5%**	**99%**
FR	> 252	> 252	> 252	210	150	115	112	77	58	66	52	35
GR	> 252	> 252	> 252	223	156	110	90	57	48	140	100	70
US	118	72	54	120	80	52	31	25	12	80	55	47
TRY	55	41	25	24	18	12	15	12	8			
FR-GR	> 252	> 252	> 252	212	152	105	75	51	40	188	146	100
FR-US	> 252	> 252	> 252	175	125	80	62	47	38	100	60	50
FR-TRY	> 252	200	142	68	42	25	40	22	16			
FR-GR-US	> 252	> 252	> 252	200	142	112	55	48	36	182	133	98
GR-US-TRY	> 252	> 252	210	77	50	28	33	24	21			
FR-GR-US-TRY	> 252	> 252	> 252	138	100	62	62	48	25			

Trying to make sense out of these data we conclude the following:

Table 2.3: Encounter dates in months

	GARCH	PCA	ICA	DNS	GARCH	PCA	ICA	DNS	GARCH	PCA	ICA	DNS
	95.00%				**97.50%**				**99.00%**			
FR	12.00	10.00	5.33	3.14	12.00	7.14	3.67	2.48	12.00	5.48	2.76	1.67
GR	12.00	10.62	4.29	6.67	12.00	7.43	2.71	4.76	12.00	5.24	2.29	3.33
US	5.62	5.71	1.48	3.81	3.43	3.81	1.19	2.62	2.57	2.48	0.57	2.24
TRY	2.62	1.14	0.71		1.95	0.86	0.57		1.19	0.57	0.38	
FR-GR	12.00	10.10	3.57	8.95	12.00	7.24	2.43	6.95	12.00	5.00	1.90	4.76
FR-US	12.00	8.33	2.95	4.76	12.00	5.95	2.24	2.86	12.00	3.81	1.81	2.38
FR-TRY	12.00	3.24	1.90		9.52	2.00	1.05		6.76	1.19	0.76	
FR-GR-US	12.00	9.52	2.62	8.67	12.00	6.76	2.29	6.33	12.00	5.33	1.71	4.67
GR-US-TRY	12.00	3.67	1.81		12.00	2.38	1.14		10.00	1.33	1.00	
FR-GR-US-TRY	12.00	6.57	2.95		12.00	4.76	2.29		12.00	2.95	1.19	

2.5 Conclusion

We have compared in this paper different methods for computing the capital charge of a commercial bank based on a Eurobonds portfolio example and we have explored the performance in an out-of-sample forecasting based on the number of violations.

These approaches might be used as internal models compared to Basel's SBA in order to define a chosen time horizon and confidence level vis a vis the 'standard method'.

Approaching Basel's method, the results show:

- For European markets, GARCH method computes a similar capital requirement as the SBA for a minimum of one year time horizon.
- Comparing PCA and ICA we can conclude that the ICA is more restrictive for single currency denoted and mixed portfolios.
- PCA gives a seven months, 97.5% adequacy parallel to the three months given by the ICA for FR and GR portfolios. We add a PCA requirement of 4 months horizon for the US portfolio facing a one month limit given by the ICA.
- In the mixed portfolios PCA sets (at 97.5%) a limit of six to seven months except when the Turkish lira is involved, ICA shows a lower encounter point of two months.
- The DNS on the 97.5% gives an adequate capital charge between three and five months.
- In the mixed portfolios DNS method on the 97.5% requires a time horizon between three and seven months.

Based on the previous, our recommendations are:

→ For the Eurozone:

- GARCH capital charge at twelve months would be equivalent to the SBA for a level of 97.5 %.
- GARCH does not account for inter-maturities correlations therefore an ICA or PCA approach would be more rational:
  - 7 months PCA 97.5 % on a one country or combined countries level.
  - 3 months ICA 97.5 % on a country level and 2 months when combined.
- DNS would inquire an average of 3 months for each country and 6 months for a multi-European portfolio.

→ For the US:

- GARCH imposes a 4 month horizon for 97.5% confidence level.
- 97.5% PCA for less than 4 months capital charge would do it and a 1 month ICA.
- An average of 3 months DNS results in a close capital charge as the SBA's requirement.

→ For the Turkish market:

- TRY is too volatile to be adequately represented by ICA or DNS models: it can be used for very short term : one month or less PCA (97.5%).

→ When combining US and Euro markets:

- GARCH results could remain applicable (at the one year horizon).
- PCA method time horizons' is half a year.
- ICA results in a 2 months time horizon
- whereas DNS methods time horizons' is between 3 and 6 months (due to the change in the distribution of the portfolio and the weakness of the VaR in that case).

→ When combining the Turkish lira with any of the US dollar or Euro portfolio: PCA and ICA approach an average of 2.5 months.

The goal of this work was to provide banks with a tool that explains the econometric concept behind Basel's SBA approach in order to fix the time horizon and confidence level of their capital requirement in the trading portfolio. In addition, these models could provide an internal approach with customized coefficients and parameters.

In June 2015, a new consultative document was issued by the BCBS on the 'Interest rate risk in the banking book, presenting new approaches to handle this book's capital charge computation and suggests dividing this amount between the first and second pillar. Incorporating the banking book in the first pillar is a new approach, because that segment was reserved for the trading book. Doing so, a similar methodology to the SBA would be inquired for the banking book. Our next step would be to construct an internal model that mimics the proposed approach to compute the local parameters for the capital charge computation and interest rate shock scenarios applications.

Appendices

Appendix 2.1: Numerical example for approaching the SBA

- **Case 1:**
  Let us consider a bond with regular payments (not a zero coupon bond), the following equations explain the link between the portfolio′s duration and the SBA computation method:

  Portfolio price: $P = \sum_{t=1}^{T} C_t e^{-r_t t}$

  Net sensitivity: $NS = \frac{\sum_t C_t e^{-r_t t} - \sum_t C_t e^{(-r_t - 0.01\%)t}}{0.0001}$

  Weighted sensitivity: $WS = RW \frac{\sum_t C_t e^{-r_t t} - \sum_t C_t e^{(-r_t - 0.01\%)t}}{0.0001}$

  Weighted sensitivity = K

  Capital charge: $CC = \frac{K}{\text{initial portfolio value}}$

  Capital Charge: $CC = RW \frac{\sum_t C_t e^{-r_t T} - \sum_t C_t e^{(-r_t - 0.01\%)t}}{0.0001 * \sum_t C_t e^{-r_t T}}$

  Or, $e^x = 1 + x + o(x)$

  Capital charge: $CC = \frac{RW}{0.0001} \frac{\sum_t C_t e^{-r_t T}(0.0001t + o(t))}{\sum_t C_t e^{-r_t T}} = \frac{RW}{0.0001}(0.0001 * Duration + o)$
  Capital charge: $CC = RW * Duration + o$

  Exemple 1: One zero coupon bond maturing after one year

SBA method		Proxi formula	
RW	0.015	*RW*	0.015
i	2.50%	*i*	2.50%
Price	97.53	Price	97.53
$i + 1$ bps	2.510%	Duration	1
Price $(i + 1bps)$	97.52		
Sensitivity	97.53		
Weighted sensitivity	1.46		
Capital Charge	1.499925%	Capital Charge	1.500000%

- **Case 2:**
  Considering two different bonds with the same currency the results are as follow:
  Bond 1: $P_1 = \sum C_t e^{-r_t t}, D_1 = \frac{\sum t C_t e^{-r_t t}}{P_1}$
  Bond 2: $P_2 = \sum B_j e^{-r_j j}, D_2 = \frac{\sum j B_j e^{-r_j j}}{P_2}$
  Net sensitivity:
  $NS_1 = \frac{\sum_t C_t e^{-r_t t} - \sum_t C_t e^{(-r_t - 0.01\%)t}}{0.0001}$
  $NS_2 = \frac{\sum_j B_j e^{-r_j j} - \sum_j B_j e^{(-r_j - 0.01\%)j}}{0.0001}$
  Weighted sensitivity: $WS_1 = \frac{RW_1}{0.0001} \sum_t C_t e^{-r_t t}(1 - e^{-0.0001t})$
  $WS_1 = RW_1 * D_1 * P_1$
  $WS_2 = \frac{RW_2}{0.0001} \sum_j C_j e^{-r_j j}(1 - e^{-0.0001j})$
  $WS_2 = RW_2 * D_2 * P_2$
  $K = \sqrt{WS_1^2 + WS_2^2 + 2\rho_{1,2} WS_1 WS_2}$
  Capital charge:
  $CC = \frac{RW_1 P_1 D_1 + RW_2 D_2 P_2}{P_1 + P_2}(1 + (\rho_{1,2} - 1)\frac{RW_1 D_1 P_1 RW_2 D_2 P_2}{(RW_1 D_1 P_1 + RW_2 D_2 P_2)^2})$
  Exemple: two zero coupon bonds, maturities one and two years having the same currency.

SBA method		Proxi formula	
RW_1	0.015	RW_1	0.015
i_1	2.50%	i_1	2.50%
$Price_1$	97.53	$Price_1$	97.53
$i1 + 1$ bps	2.51%	RW_2	0.0115
$Price_1(i_1 + 1bps)$	97.52	i_2	3.00%
RW_2	0.0115	$Price_2$	94.18
i_2	3.00%	Duration 1	1
$Price_2$	94.18	Duration 2	2
$i_2 + 1$ bps	3.01%	Correlation	0.75
$Price_2(i_2 + 1bps)$	94.16		
Sensitivity 1	97.53		
WS_1	1.46		
Sensitivity 2	188.33		
WS_2	2.166		
Capital Charge	1.775338%	Capital Charge	1.779129%

- **Case 3:**
In order to see the influence of the diversity in currencies, we consider 2 bonds with different currencies therefore we consider two buckets:
Bond 1: $P_1 = \sum C_t e^{-r_t t}, D_1 = \frac{\sum t C_t e^{-r_t t}}{P_1}$; Bond 2: $P_2 = \sum B_j e^{-r_j j}, D_2 = \frac{\sum j B_j e^{-r_j j}}{P_2}$
Net sensitivity: $NS_1 = \frac{\sum_t C_t e^{-r_t t} - \sum_t C_t e^{(-r_t - 0.01\%)t}}{0.0001}$; $NS_2 = \frac{\sum_j B_j e^{-r_j j} - \sum_j B_j e^{(-r_j - 0.01\%)j}}{0.0001}$
Weighted sensitivity:
$WS_1 = \frac{RW_1}{0.0001} \sum_t C_t e^{-r_t t}(1 - e^{-0.0001t}) = RW_1 * D_1 * P_1$
$WS_2 = \frac{RW_2}{0.0001} \sum_j C_j e^{-r_j j}(1 - e^{-0.0001j}) = RW_2 * D_2 * P_2$
Having two currencies results in having two buckets: $K_1 = WS_1 \text{and} K_2 = WS_2$
Basel SBA implements a correlation factor of 0.5 between currencies:
Capital Charge: $K_{total} = \sqrt{K_1^2 + K_2^2 + 0.5 * (S_1 S_2 + S_2 S_1)}$ where $S_i = \sum WS_i$
Capital Charge: $CC = \frac{RW_1 P_1 D_1 + RW_2 D_2 P_2}{P_1 + P_2}(1 - \frac{RW_1 D_1 P_1 RW_2 D_2 P_2}{2(RW_1 D_1 P_1 + RW_2 D_2 P_2)^2})$
Example: two zero coupon bonds, maturities one and three years having different currencies.

SBA method		Proxi formula	
RW_1	0.015	RW_1	0.015
i_1	2.53%	i_1	2.53%
$Price_1$	97.50	$Price_1$	97.50
$i_1 + 1$ bps	2.54%	RW_2	0.0115
$Price_1(i_1 + 1bps)$	97.49	i_2	12.67%
RW_2	0.0115	$Price_2$	68.38
i_2	12.67%	Duration 1	1
$Price_2$	68.38	Duration 2	3
$i_2 + 1$ bps	12.68%	Inter-buckets	0.5
$Price_2(i_2 + 1bps)$	68.36		
Sensitivity 1	97.50		
WS_1	1.46		
Sensitivity 2	205.11		
WS_2	2.36		
Capital Charge	2.013159%	Capital Charge	2.031698%

Appendix 2.2: Data statistics

Viewing these statistics, we can see that France, Germany and USA have relatively low interest rates compared to an average of 12% rate for the Turkish market. In addition, the standard deviation representing roughly the volatility of a market is larger by a factor of four in the emerging market. Comparing the European markets to the American status, we can clearly see a large resemblance in trends and volatilities; however US remains the government with the lowest rates.

Table 2.4: FRANCE data statistics

Maturity	mean	std	min	max
3m	0.021	0.016	-0.002	0.051
6m	0.022	0.016	-0.004	0.053
1y	0.023	0.016	-0.002	0.053
2y	0.025	0.015	-0.002	0.053
3y	0.027	0.015	-0.002	0.053
4y	0.029	0.014	-0.001	0.054
5y	0.031	0.013	0.000	0.054
6y	0.032	0.013	0.000	0.054
7y	0.034	0.012	0.001	0.055
8y	0.036	0.012	0.001	0.057
9y	0.037	0.012	0.002	0.057
10y	0.038	0.011	0.004	0.059
15y	0.042	0.010	0.006	0.059
20y	0.045	0.011	0.008	0.067
30y	0.045	0.010	0.010	0.065

Table 2.5: GERMAN data statistics

Maturity	mean	std	min	max
3m	0.030	0.024	-0.003	0.099
6m	0.030	0.023	-0.002	0.100
1y	0.031	0.022	-0.003	0.095
2y	0.032	0.022	-0.003	0.091
3y	0.034	0.021	-0.002	0.089
4y	0.037	0.021	-0.002	0.088
5y	0.038	0.020	-0.002	0.087
6y	0.040	0.020	-0.001	0.086
7y	0.042	0.020	-0.001	0.085
8y	0.043	0.020	0.000	0.084
9y	0.044	0.019	0.000	0.083
10y	0.044	0.019	0.001	0.082
15y	0.048	0.017	0.002	0.082
20y	0.051	0.017	0.004	0.084
30y	0.051	0.018	0.005	0.086

Table 2.6: US data statistics

Maturity	mean	std	min	max
3m	0.018	0.019	0.002	0.057
6m	0.019	0.019	0.002	0.058
1y	0.020	0.019	0.003	0.058
2y	0.022	0.018	0.003	0.057
3y	0.025	0.017	0.004	0.057
4y	0.027	0.016	0.006	0.058
5y	0.029	0.015	0.007	0.058
6y	0.031	0.014	0.009	0.058
7y	0.033	0.013	0.011	0.058
8y	0.034	0.013	0.013	0.059
9y	0.036	0.012	0.014	0.059
10y	0.037	0.012	0.015	0.059
15y	0.040	0.011	0.019	0.060
20y	0.041	0.011	0.021	0.061
30y	0.042	0.010	0.021	0.061

Table 2.7: TRY data statistics

Maturity	mean	std	min	max
3m	0.112	0.042	0.044	0.227
6m	0.118	0.046	0.045	0.240
1y	0.123	0.049	0.046	0.254
2y	0.126	0.050	0.049	0.267
3y	0.127	0.048	0.052	0.273
4y	0.125	0.046	0.055	0.271
5y	0.123	0.044	0.057	0.267
6y	0.124	0.044	0.058	0.267
7y	0.124	0.044	0.059	0.267
8y	0.124	0.044	0.061	0.267
9y	0.125	0.043	0.063	0.267
10y	0.125	0.043	0.064	0.267
15y	0.125	0.043	0.063	0.267
20y	0.126	0.043	0.063	0.267
30y	0.126	0.043	0.063	0.267

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Chapter 3

Counterparty Credit Risk in OTC derivatives under Basel III

Recent financial crisis were the root of many changes in regulatory implementations in the banking sector. Basel III is attempting to add rules permitting financial institutions to avoid all the major pitfalls that existed in earlier versions. The inaccurate accounting for the counterparty credit risk was a main player in the subprime crisis resulting in large amounts of exposures and losses. Basel previously covered the default capital charge for counterparty exposures however, the crisis showed that more than two third of the losses related to this risk emerged from the exposure to the movement of the counterparty's credit quality and not its actual default therefore, Basel III divided the required counterparty risk capital into two categories: the traditional default capital charge and an additional counterparty credit valuation adjustment (CVA) capital charge. In this article, we explain the new methodologies presented in the latest Basel publications to compute these capital charges on the OTC market: the standardized approach for default capital charge (SA-CCR) and the basic approach for CVA (BA-CVA). Based on historical calibration and future estimations, we built internal models in order to compare them with the amended standardized approach. Up till June 2015, interest rate and FX derivatives constituted more than 90% of the total OTC notional amount traded, based on this figure we constructed our application on portfolios containing only such instruments and computed their total counterparty capital charge under both standardized and internal approaches. The analysis reflected different impacts of the netting and collateral agreements on the regulatory capital depending on the typologies of the instruments. Moreover, results showed an important increase in the capital charge due to the addition of the CVA demands reaching sometimes the same value as the default capital charge, doubling therefore the demanded capital.

Keywords: Counterparty Credit Risk, SA-CCR, CVA, OTC derivatives, Basel III

3.1 Introduction

Derivatives market witnessed an important bloom in recent decades due to their increasing utility in our financial markets. Several typologies and complexity levels of such instruments are used either in a regulated exchange traded manner or in an over the counter fashion. Instruments could be swaps, options, futures, forwards... Exchange traded activity started in 1970 following certain rules and 'standardized 'formats whereas over the counter (OTC) market came in 1990 as an 'irregular 'market with various customizable trades therefore it is a more risk vulnerable environment. OTC market has a larger volume due to the higher profit margin and wider bid-ask spreads. Trying to reduce the risk on the OTC market, clearing houses were created in order to give all the counterparties a guarantee not to have any open positions and to force applications of the agreed upon rules.

Derivatives hold several types of risks such as market, liquidity and credit, however the credit risk in such instruments is not the typical credit risk that we encounter when passing a loan, it is the counterparty credit risk. The counterparty credit risk differs from the traditional credit risk by two points: the bilateral risk profile and the variation of the exposure depending on market and counterparty behavior. Recent crises emphasized the faulty practices regarding the OTC derivatives capital charge computation from a counterparty credit risk point of view. Basel II had implemented methods to compute the default capital charge of the counterparty credit risk beard in derivatives however in the sub-prime crisis two thirds of the losses did not result from such category of counterparty risk. A new risk source was highlighted: the risk resulting from the credit valuation of the counterparty noted the credit valuation adjustment risk (CVA).

In this paper our aim is to describe the current OTC market, to briefly note the previously applied regulatory methods for the counterparty credit risk then to explain and apply the new methods in order to compute the capital requirements on typical portfolios. The paper proposes also an internal approach to compute the same figures based on historical behavior and future market experts' estimations. Section 1 introduces the counterparty credit risk, Section 2 details the default capital charge whereas Section 3 details the CVA risk capital charge. Section 4 presents the application of such techniques compared to internal approaches on sample portfolios and finally Section 5 concludes on the results.

3.2 Counterparty Credit Risk

Counterparty Credit risk adds to all these risks related to OTC derivatives however, this type of risk has the major impact on the capital charge computation. Counterparty credit risk covers two facts: the defaults of the counterparty or the decrease in its credit quality (cf. Beier et al., 2010). In both scenarios, a bank would try to replace the instrument held or re-evaluate its worthiness. In order to compute this 'replacement cost' and 'potential future exposure' different factors are involved such as: Mark-to-market exposure, liquidity risk following a counterparty's default, operational risk as in the process of managing the positions after a change had occurred or even in managing the margins or collaterals of a certain agreement and finally legal risk related to enforcement for the application of the deals conditions.

As the use of derivatives has grown, specially on the OTC market, regulators are continuously trying to implement new approaches that reflect as adequately as possible the counterparty risk en-globed by these instruments and therefore making their approaches more and more sophisticated (cf. Ingves, 2013).

3.2.1 Transition to Basel III

In an attempt of improving capital framework for OTC derivatives under Basel III (cf. BCBS, 2010), several reforms were put in place:

- Wrong way Risk is more adequately evaluated by not taking recoveries in the loss given default (LGD) computation (the amount lost in case of the counterparty's default).
- The computation of the portfolio exposure is required to take into account a stressed period values (in LGD calibration).
- New method for collateralized transactions evaluations to capture the exposure over a full year of inception.
- Standards for initial margining have been strengthen.
- The asset value correlation parameter was increased by 25% to reflect the correlations between financial institutions raising the risk weights.

Another important change in Basel III is the addition of a credit valuation adjustment (CVA) capital charge (cf. CRDIV, 2014) to capture the risk of mark to market losses on the expected counterparty credit risk. Total losses from CVA were double the losses from defaults (66% from CVA and only 33% of the losses are due to defaults).

The CVA capital charge is expected to double the capital charge for derivatives however, banks are not going to be asked to put any additional CVA charge if the derivatives are centrally cleared: This is an incentive to clear through a central counterparty clearing house (CCP).

3.2.2 Default Capital Charge computation

All banks are required to hold capital against the variability in the market value of their OTC instruments: they need to capitalize for default risk. As it is well know for Basel amended approaches two possibilities are entitled: a standardized approach and an internal model implementation. In the following, we are going to discuss briefly the characteristics and method scheme of each of these methods in order to apply them in the following part of this work and compare their figures.

Standardized Counterparty Credit Risk approach (SA-CCR)

SA-CCR is the new standardized approach for computing default counterparty credit risk (cf. BCBS, 2014 a). It was presented and revised by April 2014 and is in order to be implemented by January 2017. Different papers described this method (cf. FEI, 2014), in our work we try to summarize and apply it on different portfolios under different conditions in order to understand the behavior of this practice.

Main objectives of this method implementation were to be:

- Suitable to be applied on different kinds and specifications of derivatives transactions
- Easy and simple implementation techniques
- Better than the methods that preceded
- More risk sensitivity reflection

Computing the capital charge is our main aim and this figure is given by:

$$\text{Default Counterparty Capital Charge} = \text{Exposure at default} \times \text{Risk weight} \times 8\% \tag{3.1}$$

where the SA-CCR EAD (Exposure at default) is our key figure, the risk weight is amended by Basel and the 8% reflects the pillar 1 obligation.

Computing the EAD would need to be held on each netting set level on a hedging set basis:

$$EAD = 1.4 \times (RC + PFE) \tag{3.2}$$

where RC is the replacement cost and PFE the potential future exposure.

The concept of Equation (3.2) is referring to is the fact that the exposure to an instrument is the sum of its present value and the future potential values. The alpha factor is added as an insurance to cover the risk and the value of alpha is calibrated based on several internally generated models (seen in previous counterparty credit risk models), therefore this coefficient is kept constant all through the computation.

Hedging sets are defined as follows (cf. BCBS, 2014 a, p.12-13):

1. Interest rate: a hedging set is defined for one same currency further divided into maturities, long and short positions fully offset within maturity categories, across maturity categories partial offset is recognized
2. Foreign exchange: same currency pairs form same hedging sets, full offset is only permitted within a same pair
3. Credit derivatives and Equity derivatives: in these two categories each asset class forms a hedging set, full offset is permitted for a same entity (index or name) whereas partial offset between derivatives is applied when referring to different entities
4. Commodity derivatives: four hedging sets are in place: energy, metals, agriculture and others. No offset among these four categories. In a same hedging set, full offset for same commodity is permitted and partial offset is applied when handling different commodities.

The EAD formula changes in case the trade is margined or un-margined:

- If margined: RC represents the exposure if the counterparty defaults at time $t = 0$ assuming the close-out does not take time and PFE is the change in value during the period between the default and the deployment of the collateral.
- If un-margined: RC is the present exposure and PFE is the potential increase in exposure over a one-year time horizon.

Replacement Cost

The *RC* is computed following two formulas: if the trade is margined or not (more details in BCBS (2014), p. 4-7.

For un-margined transactions:

$$RC = max(0; V - C) \tag{3.3}$$

where

- V is the current market value of the derivatives
- C is the net haircut collateral held

Not having any margin, at time $t = 0$ the replacement cost would depend on two possible outcomes: the instrument's value is in our favor or not. If the value of the instrument is higher than the collateral a default of the counterpart would result in a loss equal to $V - C$ the value of the instrument minus the collateral value, if not, no loss is included: which explains the *RC* formulation in the un-margined case.

For margined transactions:

$$RC = max(0; V - C; TH + MTA - NICA) \tag{3.4}$$

where

- TH is the positive threshold before the counterparty send the bank collateral
- MTA is the minimum transfer amount applicable to the counterparty
- $NICA$ any collateral posted by the counterparty minus the one posted by the bank (net value)

In this case the margin should be taken into account for the computation of the replacement cost: if the value of the instrument is inferior to the value of the collateral and the collateral posted by the bank is inferior to the one posted by the counterparty, the loss will be null. However, if any of the previously denoted figures is positive the replacement cost will be equal to it: if the posted collateral is more than the collateral of the counterparty or if the value of the instrument is higher than the total collateral the bank would have to cover these differences as a replacement cost.

Potential Future Exposure

PFE is given by:

$$PFE = \text{multiplier} \times Add - On^{aggregate}$$

where the multiplier recognizes excess of collateral and negative mark-to-market, and the add-ons are calculated for each asset class.

Computing the multiplier (cf. BCBS 2014 a, p.8), with a floor of 5% is computed as follows:

$$\text{multiplier} = \min\left[1; floor + (1 - floor) \times \exp\left(\frac{V - C}{2 \times (1 - floor) \times Add - on^{aggregate}}\right)\right].$$

The multiplier formula is built in a way to account for over-collaterization: the multiplier is normally at 1 however, if the bank chooses to over-collaterize the instrument they are holding, this multiplier will be inferior to 1 therefore giving the bank the advantage of their extra-safety arrangement.

And the add-on computation follows these steps:

1. Define the transaction primary risk factor.
2. Allocate it to an asset class: Interest rate (IR), Foreign exchange (FX), equity, credit or commodity
3. Compute the adjusted notional amount (for IR and credit duration is included).
4. Get the maturity factor (whether margined or not).
5. Multiply the supervisory delta by the adjusted notional (+ or - 1 if long or short).
6. Multiply it by the given supervisory factor to reflect volatility.
7. Aggregate by hedging sets and asset-class level.

For more details on the specific computation of the Add-on for each asset class, please refer to the Basel document, BCBS 2014, p.8 till p.18.

The SA-CCR add-on computation method is based on a set of assumptions in order to result in the previously cited formulas. These assumptions are the following:

- All trades are at the money ($MtM = 0$).
- The banks neither hold nor post collateral.
- No cashflows are present before the one year horizon.
- The evolution process of instruments follows a Brownian motion with zero drift and fixed volatility.

We note the important impact of the maturity factor on the computation: this latter depends on the portfolio: margined or not. If the portfolio is un-margined, the maturity factor (MF) applied is equal to:

$$MF^{un-margined} = \sqrt{\frac{min(1year, Maturity)}{1year}}. \tag{3.5}$$

However, if the portfolio is margined, MF depends on the remargining frequency. Basel amends a certain margin period of risk (MPOR) depending on the characteristics of the deals considered, this margin represents the closing time between the default of the counterparty and the margin payment (cf. BCBS 2014 a, p. 13 paragraph 164).

$$MF^{margined} = \frac{3}{2}\sqrt{\frac{MPOR}{250}} \tag{3.6}$$

where $MPOR$ is defined by the frequency: for daily re-margining $MPOR$ is equivalent to 10. The general formula for an N remargining per day frequency is:

$$MPOR = 10 + N - 1. \tag{3.7}$$

A daily re-margin is the most conservative, therefore we chose this frequency as a base of our application portfolios (in Section 3.4).

However, we note that the $3/2$ multiplier maintained by Basel in order to approach the EE of a margined transactions to the one of an un-margined transaction for MPOR (cf. BCBS, 2014 b) paragraph 2.2) is resulting in double accounting for the shock (1.5×1.4).

Several comments were presented to try and remove this multiplier, such as the comments by Deutche bank, however, the multiplier remains present in the finalized version of the method.

A brief description of the SA-CCR is shown in **Figure 3.1**.

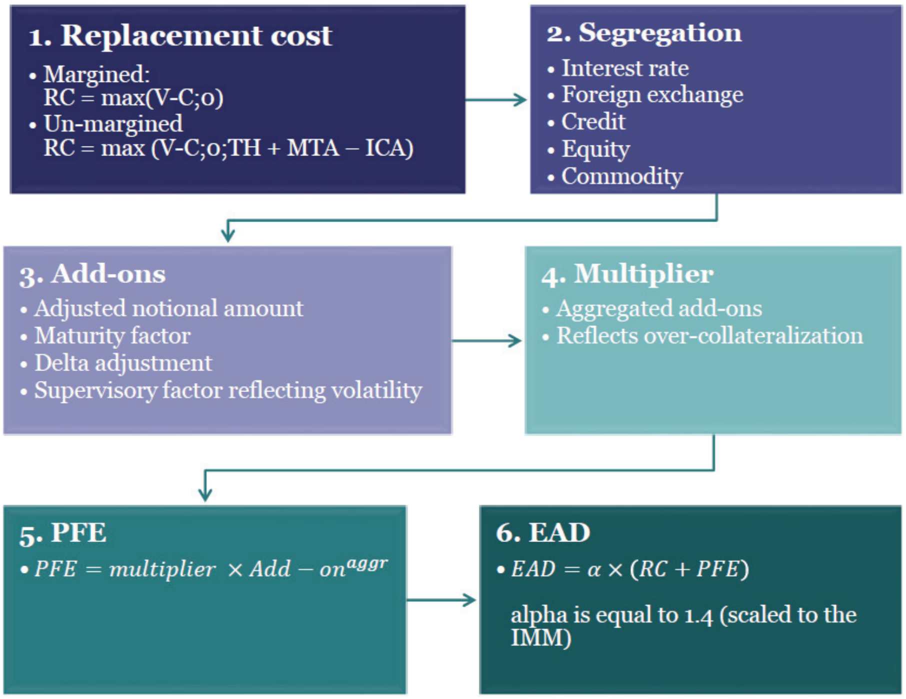

Figure 3.1: SA-CCR capital charge computation process

Internal model method (IMM)

As the habit went, all internal models to be applied for banks should be accepted by the supervisor entitled for this bank (the national regulator). The bank in our case study is free to chose to model internally the *EAD* for the OTC derivatives. Having this in mind, Basel implemented in its third version requirements that should be respected in order to get approval for the proposed internal model (cf. BCBS, 2010). Please note that due to several different approaches that could be considered in the internal model approach, in a consultative document (cf. BCBS, 2016 a) Basel proposed to floor the IMM capital charge to a certain percentage of the SA-CCR capital charge or better yet remove the IMM as an approved method to compute and report capital charges under the counterparty credit risk.

However, all OTC instruments that were not included in the internal model or that could not assume approval to be globalized under the internal model should be treated through the standardized approach. We shall briefly describe the requirements for the *EAD* internal model but we note that these requirements are required on a permanent basis and continuous check-ups will be put in place in order to ensure the fully compliance to these rules all through the period of application of the chosen internal model.

In an attempt to make this more pleasant for readers and more easy to discuss the conditions for the implementation of an internal model will be represented as bullet points under each categories of requirements:

- The model should specify a forecasting distribution for changes in market value such as interest rate or foreign exchange rate.
- For margined counterparties, the model should also capture the future behavior of the collateral in question. Note that no particular form of model is required.
- Determining the default capital charge should be based on the greater computation using: once the current market data to calibrate the projection models and once a stressed calibration. In both cases the time frame

should be three years and in the stressed conditions it should cover a stressed period in between (three years containing a stress among them).

- The computation will follow these given steps : the Exposure at Default (*EAD*) is the product of a previously calibrated (and negotiated) α factor and the Effective Expected Positive Exposure:

$$EAD = \alpha \times EEPE. \tag{3.8}$$

Effective Expected Positive Exposure (EEPE) relies on internal model to predict counterparty exposures, typically simulating underlying market risk factors out to long horizons and revaluating counterparty exposures at future dates along the paths simulated, it is the weighted average of the Efective Expected Exposure (EEE).

$$EEPE = \sum_{k=1}^{min(1year,maturity)} EEE_k \times \Delta_k. \tag{3.9}$$

The EEE is the increasing function of the Expected Exposure (EE): this amends a more restrictive approach, once an exposure is hit the method does not permit a decrease in the exposure for future dates.

$$EEE_k = max(EEE_{k-1}, EE_k) \tag{3.10}$$

where $\Delta_k = t_k - t_{k-1}$ and EE_k being the average exposure at future date k across possible future values of relevant market risk factors, and alpha set for 1.4 however a discussion permitting lower or greater alpha is possible (floored at 1.2). A more detailed look on these formulas is clearly presented in Pykhtin's article (cf. Pykhtin, 2007).

- The exposure should not only be limited for a given time horizon (ex: one year), it should cover the entire life of the portfolio (the OTC portfolio in our case).
- Again for margined transactions, the internal model should account for the re-margining period, the mark-to-market valuation and a sets of floors set for the time horizons of deals.
- An independent management unit responsible for calculating and making calls for margin should be put in place.
- The bank must present: adequate documentation for the counterparty credit risk (CCR) management process, validation of the models, organizational approval, accurate reporting and reflective results.
- Before starting to use the model, a bank should calculate it for at least one year before implementation in order to have a set of observed outcomes of the chosen approach.

In the rest of this chapter, we will choose for each case a given forecasting model in order to project the risk factors (interest rate and foreign exchange risk), calibrate it twice: once on a normal market and once in stress conditions, compute the *EE* and going up the formulas recover the *EAD* for the instrument in question in the both cases, the maximum *EAD* will be our *IMM* exposure at default.

We note that the calibration, the re-evaluation and the models chosen for the IMM could change the capital charge amended by such approaches: the relative variability for IMM appears to be considerable between banks. Basel committee conducted an exercise in an attempt to compare the outcome of such models between banks and recommend a best practice for the IMM in the counterparty credit risk framework (cf. BCBS, 2015 b).

3.3 CVA Capital Charge Computation

The CVA capital charge applies to all derivative transactions that are subject to the risk that a counterparty could default. However, the scope of application does not include derivatives cleared through a clearing (central) counterparty. It also encompasses securities financing transactions that are fair-valued by a bank for accounting purposes. CVA risk could be seen as a strong link between the counterparty and the market risk however it is by nature more complex in nature than market risk on the trading book leading to different frameworks and choices about precise implementation (cf. Gregory, 2015).

Recent Basel approaches amended two frameworks for the computation of this capital charge: the Fundamental Review of the Trading Book CVA framework (FRTB-CVA) and a Basic CVA approach (BA-CVA). Under the FRTB concept, banks are asked to compute the CVA sensitivities requiring the simulation of all exposures to a large panel of market risk factors. This procedure is very demanding, therefore some banks are enable to cover this calculation and therefore the basic approach is an option for these reasons (cf. BCBS, 2015 a). In February 2016, a QIS was sent by Basel to be calculated by banks on a voluntarily basis in order to measure the impact of these different approaches on the computation of the CVA capital charge QIS (cf. BCBS QIS, 2016 b).

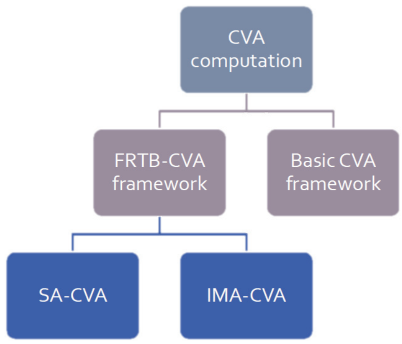

Figure 3.2: CVA capital charge computation methodologies

3.3.1 Standardized CVA (SA-CVA FRTB)

Eligibility Criteria:

1. Ability to compute CVA sensitivities.
2. Methodology to approximate credit spreads for all counterparties (including illiquid ones).
3. Existence of an independent CVA risk management function.

Eligible hedges: single-name instruments, proxy hedges, market risk hedges.

CVA calculation:
At least a monthly computation is entitled: for each counterparty (even if only one derivative is included).

The SA-CVA capital is the sum of delta and vega risks. Each one of these categories are divided into subcategories depending on the risk types as shown in **Figure 3.3**, and for each type a certain methodology is used to bucket the assets and to compute their sensitivity.

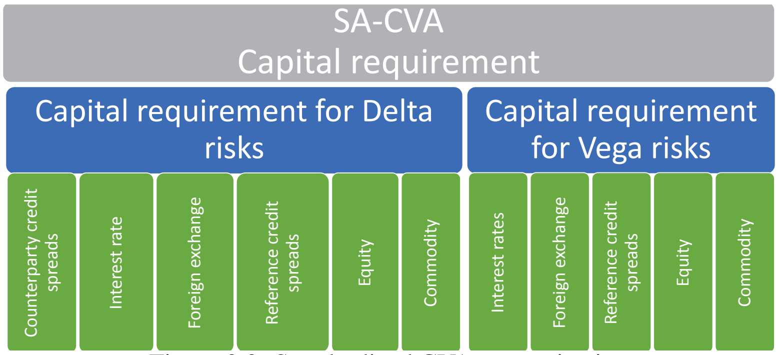

Figure 3.3: Standardized CVA categorization

For each risk type in both categories we compute (refer to BCBS(2015) p. 16-25):

- Sensitivity of the aggregate CVA
- Sensitivities of all eligible hedges
- Compute weighted sensitivities: risk weights are given by Basel for each risk type.
- The net weighted sensitivity is the sum of the weighted sensitivities of the CVA and the corresponding hedges.
- Within each bucket, weighted sensitivities are aggregated to form the capital charge of the bucket.
- Across buckets computation would result in the total required capital charge (cf. BCBS, 2015 a) p. 25-26).

3.3.2 Advanced Internal Model Method IMM-CVA FRTB

The use of this method is conditioned upon approval of supervisor's authority. Briefly citing the conditions: regular back testing, a trial period, expected shortfall approach, 97.5 confidence level, cover delta and vega risks, stressed period calibration.

The methodology is to compute internally the CVA expected shortfall (netted assumptions) and then to compute this figure for each asset types: interest rate, FX, credit spread, equity and commodities in order to sum all of them and get the gross expected shortfall.

The average of the two expected shortfalls is considered and a regressive formula is put in place in order to compute the required capital charge.

3.3.3 Basic CVA (BA-CVA)

The basic CVA approach is for banks that are not able to compute the CVA sensitivity or does not have the approval of their authorities to use the FRTB-CVA (cf. BSCBS 2015 a, p.27-30). However, this approach is know to be very demanding and very conservative in terms of risk weights placed by Basel.

Before detailing the computation of the capital charge it is important to cite very briefly the eligible hedges in this framework:

- single-name CDS that references the counterparty directly, or references an entity legally attached to it or references an entity that belongs to the same sector and region of this counterparty.

- single-name contingent CDS

- index CDS

The basic CVA capital charge is given by the sum of the spread capital (K_{spread}) and the expected exposure capital (K_{EE}):

$$K_{CVA} = K_{spread} + K_{EE}. \tag{3.11}$$

The formulation of the capital charge is intuitive because the CVA is the risk a bank is facing in case of a fluctuation in the credit quality of the counterparty therefore the two main factors are the credit quality represented by K_{spread} and the expected exposure amount parallel to this change: $K_{exposure}$. Differentiation in computation apply if the portfolio is hedged or not (hedging the CVA risk or not).

Considering that no hedging strategies were put in place for hedging this kind of risk, which is the case for the majority of small and medium banks having the CVA as a relatively new capital charge computation, we will apply the following formula:

$$K_{spread}^{unhedged} = \sqrt{(\rho \sum_c S_c)^2 + (1-\rho^2)\sum_c S_c^2} \tag{3.12}$$

where S_c is the supervisory expected shortfall of CVA of counterparty c and ρ is the supervisory correlation between the credit spread of a counterparty and the systematic factor set to $\rho = 50\%$.

The second term of Equation (3.11) is given by a simple scaling of K_{spread}:

$$K_{EE} = 0.5 \times K_{spread}^{unhedged}. \tag{3.13}$$

Therefore the computation is held in the S_c term:

$$S_c = \frac{RW_{b(c)}}{\alpha} \sum_{NS \in c} M_{NS} EAD_{NS}. \tag{3.14}$$

α is non-other than the $\alpha = 1.4$ discussed earlier, EAD are the EAD internally computed (IMM) earlier on a netting set level, M_{NS} is the effective maturity of the netting set and $RW_{b(c)}$ is the risk weight set by Basel for the risk bucket $b_{(c)}$ (see BCBS (2015) p. 29 for details).

3.4 Application

3.4.1 Data Used

In the following, we chose to work on three different portfolios composed each time of one unique instrument: an interest rate swap, an FX forward and a FX plain vanilla call respectively. No netting is considered and no collateral nor margin agreements are added in this first step.
In each scenario, we computed the capital charge of the portfolio for different maturities of the instrument (going from 6 months to 5 years) in order to see the progression in time of the capital charge (in standardized or internal approaches).
The choice was made due to different causes:

- To cover several asset classes.
- To study differences between instruments with or without optionality.
- The interest rate segment accounts for the majority of OTC derivatives activity and represented around 80% of the global OTC derivatives market by June 2015.
- Foreign exchange derivatives make up the second largest segment of the global OTC derivatives market with around 13% of the market by mid 2015, and FX fowards make up half of the notional amount outstanding in this asset class.

We detail the three considered portfolio in this section:

IR swaps We start by considering a portfolio containing one interest rate swap denoted in USD: one floating leg and one fixed leg of 100 USD as notional with semi-annual payments. The fixed coupon rate is defined in a way for the present MtM of the swap to be null. We will consider different versions of this portfolio by changing the maturity of the swap: from a 6 month interest rate swap to a five year swap.

FX forward We consider a portfolio containing one FX forward USD-EUR. The forward rate is computed in such way that the present MtM is null. As we did earlier, we will consider different cases of this portfolio by changing the maturity of the forward: from a 6 month FX forward to a five year FX forward.

Plain vanilla option We consider a portfolio with a single FX plain vanilla call (USD/EUR), long position, with maturities going from 6 months up till 5 years, a notional of 100 EUR, a strike price of 1.4 (the actual spot is 1.0963). The MtM of the call is not null and it is priced using the Black and Scholes formula with the market implied volatility.

The data used are fetched from Bloomberg platform (see **Appendix 3.2** for the plots):

- USD swap curve, EURO swap curve and the FX spot rate (USD-EUR).
- For each swap curve the observed tenors are 1 month up till 50 years.
- daily frequency.
- historical observed dates: since end of April 2004 until end of April 2007.
- swap curve number of observations: 1536 per tenor (112,128 observations).
- FX curve: 1565 observations.

3.4.2 Capital charge computation

Default Capital Charge

Considering a risk weight of 100% and the pillar 1 factor as 8%, by multiplying the obtained EAD by these two components we would be able to compute the capital charge to cover the counterparty credit default risk (as seen in Equation (3.1)). Therefore in the following we will just demonstrate the EAD results, final computation will be added in the next section.

SA-CCR

IR swaps
Explaining step by step the computation will result in the following:

$$EAD = 1.4 \times (RC + PFE).$$

In an attempt to replicate the SA-CCR assumptions, we considered interest rate swaps with an initial RC equal to 0 (we compute the fixed coupons in a way that is equivalent to the floating leg cashflows).

$$RC = 0.$$

As for the PFE, it is the product of the multiplier and a given Add-on. The multiplier is here to add the characteristics neglected in the add-on assumption: referring to the assumptions of the SA-CCR add-on computation formulas p.16, no collateral is considered, therefore the multiplier is added to the formulas in order to incorporate the collaterization effect. Moreover, the multiplier is floored at 5% in order to always account for the PFE even when we have a very important collaterization. In our case, no collateral is recognized therefore the multiplier is one.

$$PFE = multiplier \times Add - on$$
$$multiplier = 1$$

The Add-on depends on the asset type, for the interest rate the Add-on is computed as the product of a maturity factor, a supervisory factor, an adjusted notional and a directional delta. The adjusted notional of the IR bucket is equal to the notional amount multiplied by the duration of the instrument for a given rate of 5%. Basel justifies the supervisory factor of 0.5% as the one year volatility of the swap rate.

$$\begin{aligned}
Add-on &= \text{Supervisory factor for IR} \times \text{Effective Notional} \\
\text{Supervisory factor} &= 0.50\% \\
\text{Effective Notional} &= \delta_i \times d_i \times MF_i \\
\delta_i &= +1 \\
d_i &= Notional \times SD_i \\
SD_i &= \frac{exp(-0.05 * S_i) - exp(-0.05 * E_i)}{0.05} \\
MF_i &= \sqrt{\frac{\min(\text{Maturity; 1 year})}{\text{1 year}}}
\end{aligned}$$

where S_i is equal to 0 in our case and E_i is equal to the maturity for each case and MF_i is defined as if in order to scale down the supervisory factor (meaning to reduce the volatility for instruments of less than one year).

Table 3.1: IR swap SA-CCR results

Maturity (years)	0.5	1	1.5	2	2.5	3	3.5	4	4.5	5
EAD (% of notional)	0.24	0.68	1.01	1.33	1.65	1.95	2.25	2.54	2.82	3.10

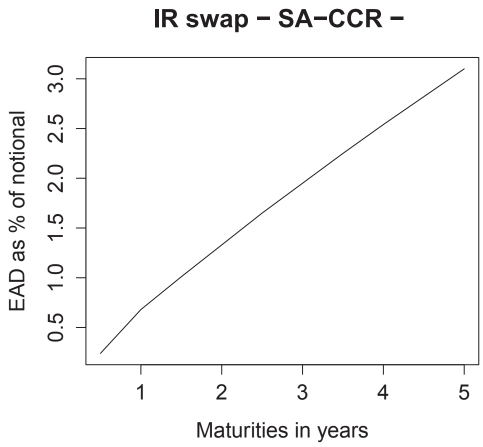

Figure 3.4: Interest rate swap EAD under SA-CCR

Not having any optionality, the IR swap only ‘variable’ is the effective notional. This latter is computed as a continuous version of a bond duration with a maturity equivalent to the maturity of the interest rate swap (details can be found in **Appendix 3.1**).
The duration being an increasing function of the maturity, the curve is expected to have an increasing trend. An additional supervisory factor is multiplied in order to ‘evaluate’ the risk of such asset class. Note that the supervisory factor for the interest rate risk is the lowest for only 0.5 %.

FX forwards The *RC* and multiplier reasoning are the same as the one previously explained in the interest rate case:

$$\begin{aligned} EAD &= 1.4 \times (RC + PFE) \\ RC &= 0 \\ PFE &= multiplier \times Add - on \\ multiplier &= 1 \end{aligned}$$

As for the Add-on, the difference in the FX type is that the effective notional (representing the volatility of the instrument after one year) is independent of the maturity therefore the effective notional is simply the notional amount.

$$\begin{aligned} Add - on &= \text{Supervisory factor for IR} \times \text{Effective Notional} \\ \text{Supervisory factor} &= 4.0\% \\ \text{Effective Notional} &= \delta_i \times d_i \times MF_i \\ \delta_i &= +1 \\ d_i &= Notional \\ MF_i &= \sqrt{\frac{\min(\text{Maturity};\ 1\ \text{year})}{1\ \text{year}}} \end{aligned}$$

Maturity (years)	0.5	1	1.5	2	2.5	3	3.5	4	4.5	5
EAD (% of notional)	3.96	5.60	5.60	5.60	5.60	5.60	5.60	5.60	5.60	5.60

Table 3.2: FX forward SA-CCR results

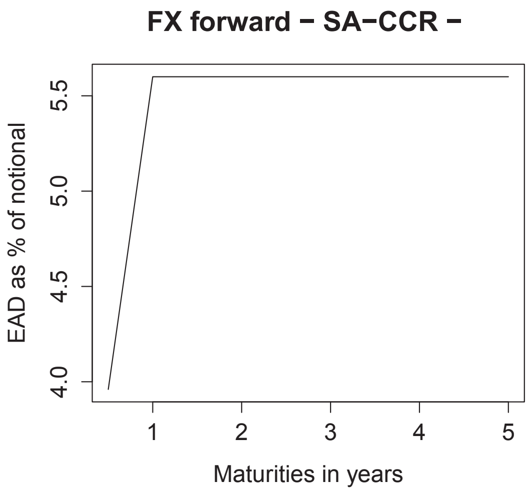

Figure 3.5: FX forward EAD under SA-CCR

Not having any optionality, nor implying the maturity into computation the FX forward *EAD* curve is divided into two parts: before the one year maturity and after one year. The computation is rather simple multiplying the notional amount, supervisory factor and capped maturity.

Note that the supervisory factor for the foreign exchange bucket is much more important than the interest rate amended factor (by 8 times) and it is equal to 4.0% justified by the regulator as the first year instrument volatility.

FX plain vanilla call

$$
\begin{aligned}
EAD &= 1.4 \times (RC + PFE) \\
PFE &= multiplier \times Add - on \\
multiplier &= 1 \\
Add - on &= \text{Supervisory factor for IR} \times \text{Effective Notional} \\
\text{Supervisory factor} &= 4.0\% \\
\text{Effective Notional} &= \delta_i \times d_i \times MF_i \\
\delta_i &= +\Phi\left(\frac{ln(\frac{P_i}{K_i}) + 0.5 \times \sigma_i^2 \times T_i}{\sigma_i \times \sqrt{T_i}}\right) \\
P_i &= \text{underlying spot} = 1.0693 \\
K_i &= \text{strike } = 1.3 \\
\sigma_i &= 15\% \text{ supervisory volatility} \\
d_i &= \text{Notional} = 100 \\
T_i &= \text{maturity} \\
MF_i &= \sqrt{\frac{\min(\text{Maturity; 1 year})}{\text{1 year}}}
\end{aligned}
$$

Maturity (years)	0.5	1	1.5	2	2.5	3	3.5	4	4.5	5
EAD (% of notional)	0.28	1.12	1.84	2.47	3.04	3.52	3.97	4.37	4.75	5.09

Table 3.3: FX plain vanilla call SA-CCR results

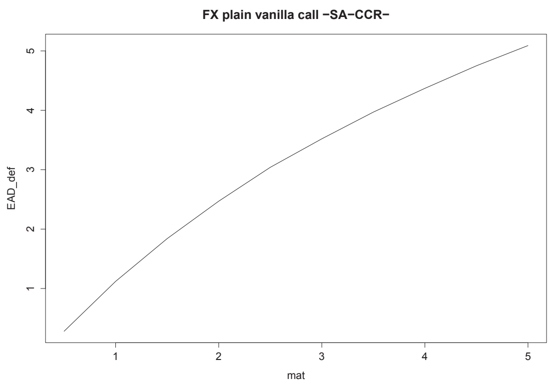

Figure 3.6: FX plain vanilla call EAD under SA-CCR

This is another example in the FX bucket therefore the supervisory factor is 4.0 %. On the first hand, we note that in this case the replacement cost is not null: it is computed as the price of the option (black and scholes). On another hand, due to the optionality of this instrument an additional factor is added: the delta. When handling instruments with no optionality, the delta factor is equal to 1 or -1 in order to reflect if we are short or long on the transactions. However, in this case the delta is computed as the normal cumulative function of a given figure. This is the risk-adjusted probability of exercise derived from the Black and Scholes formula (cf. Nielsen, 1993). In delta, a 15% volatility is amended by the regulator. Results are reflected in **Table 3.3** and **Figure 3.6**.

Internal Model Method

We build our models reflecting historical observations and incorporate expert opinions along with forecasting visions respecting in parallel the recommended practices amended by Basel such as the daily steps, the numerous simulations... Detailed explanation on both models: interest rate and FX rates are found here below.

Interest rate models

USD interest rate model

After the sub-prime crisis and European debt period, we are in a very low interest rate environment (even negative) and all expectations vote for an increase in the rates (interest rates or FX rates).
The Federal Open Market Committee (FOMC) forecasting schema (cf. FOMC, 2015) is one of the most used and trusted interest rates projections because it is based on experts opinion trying to reflect and anticipate the market behavior. These projections are those of Federal Reserve Board members and Federal Reserve Bank presidents.
The data we are using ends at $t = 0$, 27 December 2015, therefore we chose the forecasting of the FOMC in order to get an idea of the expert opinion projection of the market. FOMC presents several projection however we represent the most stressed anticipations starting December 2015 here-below:

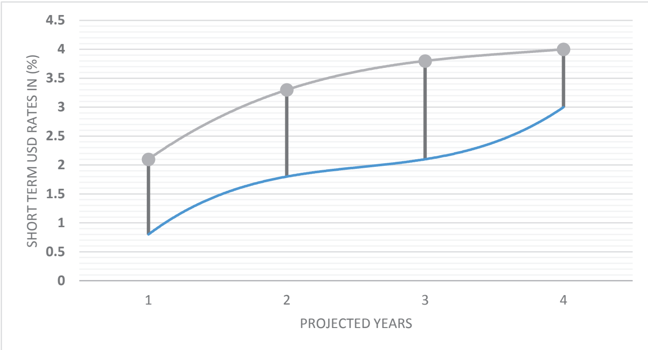

Figure 3.7: FOMC USD short rates most stressed projections

We can notice that the market tendency is to go up: 1.5% after one year, 2.3% after two years, 3.15% after three years and a 3.5% rate on the long run. Therefore we need to calibrate our historical model on a upward trend period. We chose to calibrate our internal approach to the period of rates increase of 2004-2007 and chose the best fit calibration: calibrating the models to a historical period, projecting today's yield curve based on these projections and comparing our IMM yields with the FOMC most stressed rates in order to chose the best fit.

Doing so the stressed period chosen was: 30 April 2004 till 30 April 2007 to calibrate our IMM. As an interest rate model we chose to use the well-known Vasicek approach.

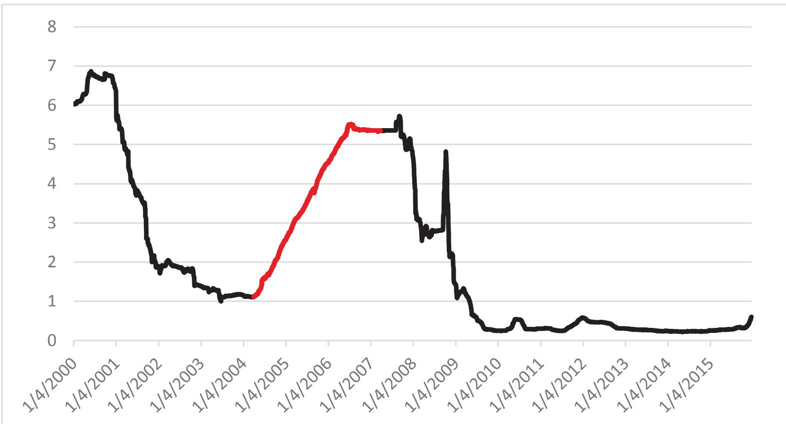

Figure 3.8: Calibration period on the USD short rates

The chosen model that we found adequately representative of the market is the Vasicek model: This is an easy model, incorporating the drift and implemented in most of the banking solutions. Choosing the most simple model was set to simplify the most this interpretation. However, Vasicek is a very sensitive model and differs amply with its calibrations however, following the previously cited technique we were able to chose a calibration that fits the market today following three main steps. These three steps should be repeated once on the stressed market calibration and once again on the current market conditions, comparing the *EAD* results we chose the maximum between both calibrations as our IMM given *EAD*. The results are as follow:

- Step 1: Calibrate Vasicek models on the historical stressed (resp. actual) period and get the parameters (cf. Planchet and Karam, 2013).

	k	θ	σ	λ	θ^*	r_0
Stressed	0.40501	0.072994	0.0015429	5.1172	0.053500	0.0535
Actual	0.00346933	0.09629892	0.00055177	-0.44712	0.0060312	0.006031

Table 3.4: Vasicek parameters for USD short rates

- Step 2: In order to fit the yield curves, we only change the speed of adjustment k in order to find the new speed at which our yields curve today would converge to the calibration conditions. Keeping all other parameters constant reflects the market and investors behavior in the calibration times (notably in times of stress). However, by changing the speed of adjustment in order to fit the actual yield curve, we change the long run of our model:

	k	θ	σ	λ	θ^*	r_0
Stressed	0.21129	0.072994	0.0015429	5.1172	0.035627	0.0535
Actual	0.053093	0.09629892	0.00055177	-0.44712	0.0081160	0.006031

Table 3.5: Vasicek parameters for USD yields generation

- Step 3: Based on these curves we evaluate our instruments and discount the cashflows in order to compute the required capital charges and *EAD*: the maximum *EAD* is chosen as the IMM *EAD*.

EUR interest rate model

The same approach is used for the EUR interest rate model: Vasicek is calibrated on the same historical upwards choc then re-parameterized to fit todays yields.

Figure 3.9: Calibration period on the EUR short rates

Foreign Exchange model

As for FX models,we use GARCH(1,1) model to reflect the volatility of these rates: it is calibrated at the same time-frame and projected. We note that the projection results of our model are in sync with Bloomberg's forecasting scenarios (most stressed) for the upcoming years.

As for the pricing models for the FX options we chose to price based on the well-know Black and Scholes formula incorporating the volatility deducted from the GARCH(1,1) model.

On a final note, in the FX instruments both interest rates and FX models are used. In order to remain homogeneous between models the same random variable is used in all models used for one given scenario.

PORTFOLIO 1: Interest rate swaps

The *EAD* value will be deduced following formulas (3.8), (3.9) and (3.10) of Section 3.2.2. As previously detailed, we started to model the IR swap curve for the USD on normal conditions and on stressed market conditions in order to get the *EAD* as the maximum of these two sets of calibrations (see **Appendix 3.3** for a detailed presentation of this approach and of the parameters estimations).

We have modeled the behavior of the interest rate swap based on this model, we have projected in the future the EE, then the EEE. Afterwards, with a $\Delta = 1/250$ (daily basis) we have computed the $EEPE$ and the $\alpha = 1.4$ resulted in obtaining the *EAD* figure. As mentioned above, this was done twice and the resulting *EAD* is the maximum exposure for both sets of conditions.

We highlight the fact that in our models, an increase in rates is amended therefore among counterparties their will always be one party with a higher exposure than another whereas in Basel the standardized approach asks for the same capital charge for both positions therefore in our IMM, the maximum exposure of both long and short positions is asked from both counterparties in order not to perturb the market equilibrium.

Trying to better clarify this previous assumption: Let us consider two counterparties with the same risk profile, if these two parties enter an interest rate swap we will have one institution paying fixed and receiving floating and the other one doing exactly the opposite. Trying to reflect the exposure of each, one party will be paying almost null capital charge whereas the other will be paying an important amount. To keep the market equilibrium (not to add a risk premium on the instrument price) and not to manipulate with the market, both counterparties are asked to place the same capital charge. This defined capital charge, in order to be the most restrictive is going to be the maximum of the short and long exposures.

The application of this process is shown here below (in % of notional), comparing it to the previously computed standardized approach *EAD* and following different maturities in years:

Maturity	0.5	1	1.5	2	2.5	3	3.5	4	4.5	5
SA-CCR	0.244	0.683	1.012	1.332	1.645	1.950	2.248	2.538	2.821	3.097
IMM	0.0987	0.433	0.821	1.085	1.364	1.578	1.838	2.052	2.303	2.515

Table 3.6: IR interest rate swap internal model results

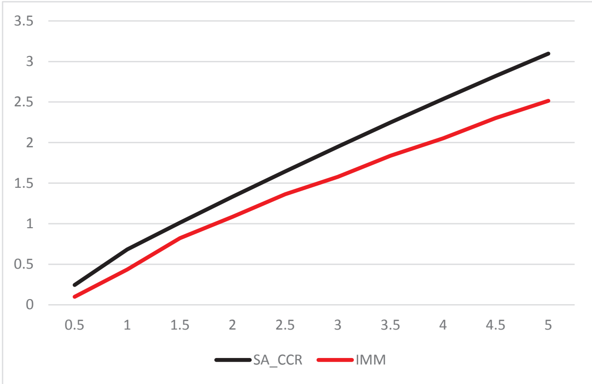

Figure 3.10: Interest rate swap EAD under the IMM

Figure 3.10 shows that following a Vasicek model we can resemble the standardized approach behavior on the maturities going from 0.5 year up to almost 5 years which is the most frequent maturities encountered in such instruments for our portfolios. However, we can notice that the IMM gives slightly lower *EAD* for all of these maturities. The IMM-EAD is almost equivalent to 80% of the SA-CCR-IMM.

PORTFOLIO 2: FX forwards

Again following the *EAD* computation technique explained in the IMM section we shall apply our own chosen models to compute the *EE* of an FX forward (USD-EUR). The methodologies used will need a part to project the yield curve and another part to project the FX rate.

Choosing the Vasicek model for the yield curves (both USD and EUR) is followed to keep consistency with the IR swap. However, for the FX rate a GARCH(1,1) was calibrated to the model and the rates were projected following this approach (refer to **Appendix 3.4** for the GARCH model details).

Again with a daily step and an alpha factor of 1.4 the results for the *EAD* as a percentage of the notional amount of the forward were as follows:

Maturity (years)	0.5	1	1.5	2	2.5	3	3.5	4	4.5	5
SA-CCR	3.96	5.60	5.60	5.60	5.60	5.60	5.60	5.60	5.60	5.60
IMM	3.09	4.33	4.48	4.46	4.61	4.87	5.21	5.50	5.84	6.24

Table 3.7: FX forward EAD internal model EAD results

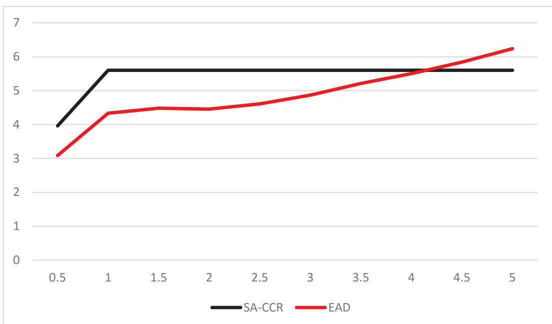

Figure 3.11: FX forward EAD under the IMM

We had previously seen the two different stages of the standardized approach *EAD* following the maturity of the instrument (before and after one year). Here, the internal model will also differ between these two stages computing the *EPE* as an average on the first year.

We can notice that the behavior of the internal model resembles the one described by the SA-CCR computation however the IMM is less demanding than the SA-CCR when using models based on one factor Vasicek and Garch(1,1). Both approaches converges to a 5.6 % EAD to notional amount. However, on a certain time range the IMM ”explodes” due to the time limits of the GARCH approach.

PORTFOLIO 3: FX plain vanilla call

The third portfolio contains a plain vanilla FX call option: measuring the EAD will demand a forecast for two risk factors: the FX rate and the interest rate (EUR and USD). Based on the same logic as previous applications, we applied a Vasicek model for the interest rates and a Garch approach for the forecast of the foreign exchange rate. Adding to that a Black-Scholes traditional pricing formulation was used based on the GARCH-computed volatilities at each time t.

Computing the EE then following the IMM process, we obtain the EAD as a percentage of the notional amount of the option as follows:

Maturity (years)	0.5	1	1.5	2	2.5	3	3.5	4	4.5	5
SA-CCR	0.28	1.12	1.84	2.47	3.037	3.52	3.97	4.37	4.75	5.09
IMM	0.31	1.13	1.65	2.10	2.48	2.84	3.15	3.43	3.69	3.94

Table 3.8: FX forward EAD internal model EAD results

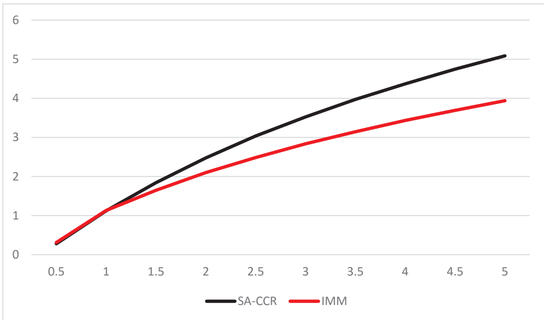

Figure 3.12: FX plain vanilla call EAD under the IMM

We can notice here that the internal model is equivalent to the supervisory capital for low maturities however after a maturity of one year we have a tendancy towards approximately 80% of the standardised approach.

We note that this might be due to the assumptions taken on the SA-CCR level assuming a 15% volatility factor whereas the GARCH approach begins by assuming lower observed volatilities on the stressed period (approximately converging towards 13%) therefore this explains the difference in behaviors depending on the maturities.

CVA capital charge

Based on Equations (3.11-3.14) we compute the capital charge for the CVA risk under the basic approach. Considering as an example, that the counteparty is a financial institution, the RW amended by Basel for this CVA approach would be $RW = 10.20\%$. Not having any hedging, CVA capital is given by:

Having assumed that no hedging is in place for the CVA risk, from equations (3.11-3.14) applying the coefficients of our cases, we can get the following shortcut formula:

$$\mathrm{CVA}_{CC} = 2 \times 0.05464 \times M \times EAD_{IMM}. \tag{3.15}$$

The computation for a one-year instrument in each asset type results in the following:

	CVA Capital Charge
One year IR swap	0.047
One year FX forward	0.47
One year FX call option	0.12

Table 3.9: CVA capital charge for one year instruments

The previous table units are the same as the notional amounts of each instrument type. The CVA capital charge being a function of the effective maturity and the *EAD*, we can simply apply the equations on the internally computed *EAD* on a netting set level in order to get this CVA charge.

Adding netting and margin effects

Having discussed the benefits of adding netting agreements and margins to our portfolio, in this section we materialize this in an actual calculation for different conditions on three given portfolios. We reconsider the same instruments seen previously, however now we will handle three composed portfolios in order to show the added effect of netting agreements and margin contracts. Trying to consider a hedging set and the effect of choosing between the standardized approach and an internal model, we consider that in each portfolio all the instruments are held with the same counterparty.

Portfolio 1: Two IR USD swaps, one long and another short, with respective maturities 0.5 and 2.5 years and notional amounts of 100 USD each. This consideration was based on the statistics of the IR swaps in the OTC market that reflects the fact that 75% of the swaps have maturities less than 5 years.

Table 3.10: Portfolio 1 composition

Trade	Type	currency	position	notional	residual maturity	MtM_0
1	IR swap	USD	short	100	0.5	0
2	IR swap	USD	long	100	2.5	0

Portfolio 2: Three FX forwards deals in the same currency pair USD/EUR: one long with a residual maturity of 0.5 years and the others short with 1 and 2.5 years as residual maturities. All forwards have the same notional 100 EUR. The choice is also attributed to the distribution of concentration based on maturities in the FX OTC instruments: more than 90% of the FX instruments have maturities less than 5 years.

Table 3.11: Portfolio 2 composition

Trade	Type	currency	position	notional	residual maturity	MtM_0
1	FX forward	USD/EUR	short	100	0.5	0
2	FX forward	USD/EUR	long	100	1	0
3	FX forward	USD/EUR	long	100	2.5	0

Portfolio 3: Two options a long position on a call of 0.5 years as maturity and a short position on another call with a residual maturity of 2.5 years (both have a 100 notional).

Table 3.12: Portfolio 3 composition

trade	type	currency	position	notional	residual maturity	MtM_0
1	FX option call	USD/EUR	short	100	0.5	-0.03
2	FX option call	USD/EUR	long	100	2.5	1.07

Not to accumulate numerous variables, we consider the threshold and the minimum transferable amount null. In other words, any positive exposure will trigger the margin agreement. As for the collateral, we implemented ISDA method in order to compute the collateral amount (cf. ISDA, 2013) as the 99th percentile of the exposure on a 10-days remargining frequency.

No independent amount was considered for the following exercises considering that both counterparties have the same profile therefore the netted collateral value is null. We hold cash collateral. These are our assumptions for the upcoming applications. The frequency term denotes the margin re-evaluation frequency, this criteria will define the maturity factor used to compute the exposure at default under the standardized approach (refer to paragraph Potential future exposure p.17). In general, daily frequencies are used therefore we applied this on our portfolios and used the 10 days MPOR amended by Basel for such remargining frequency.
Applying all the above, summaries for the margin agreements are found in **Tables (3.13-3.14-3.15)**.

Portfolio 1

Table 3.13: Portfolio 1 Margin Agreement

Frequency	Threeshold	MTA	Independent Amount	Net Collateral
Daily	0	0	0	0.12

Portfolio 2

Table 3.14: Portfolio 2 Margin Agreement

Frequency	Threeshold	MTA	Independent Amount	Net Collateral
Daily	0	0	0	1.48

Portfolio 3

Table 3.15: Portfolio 3 Margin Agreement

Frequency	Threeshold	MTA	Independent Amount	Net Collateral
Daily	0	0	0	0.80

Default capital charge

Portfolio 1

- **Step 1: Netting but no margin**
  A simple summation of the exposures at default of the previously computed results in the non-netted results. For the netting sets, SA-CCR formula for the IR class amends an aggregation of the effective notional in such a way to account for different maturity buckets:

$$\text{Effective notional} = \sqrt{\text{Eff.notional}_1^2 + \text{Eff.notional}_2^2 + 1.4 * \text{Eff.notional}_1 * \text{Eff.notional}_2} \tag{3.16}$$

  This is specified by the correlation parameters supposed by Basel between maturity buckets in the IR asset type (cf. BCBS, 2014 b) paragraph 4.1). The internal model is less demanding than the SA-CCR in both cases (netted or not). However, the netting effect decreases the exposure of the SA-CCR by an average rate of 22% whereas the IMM only decreases by 7%.

- **Step 2: Margin but no netting**
  Applying the conditions of the margin agreement cited previously on each of the trades in the portfolio, we compute the *EAD* for un-netted but margined portfolio. For the SA-CCR approach, the *RC* follows Equation (3.4) and the maturity factor is restrained because we have a daily computation ($MPOR = 10$). For the IMM, the *EAD* was recomputed following the margin agreement. When the collateral increases, the *EAD* decreases. We can notice that both methods decreased the capital charge by 72%. Note the importance of the maturity factor change: In the SA-CCR the *MF* is dependent of the *MPOR* chosen amended as 10 days for the daily margin. For the IMM, the 1.5 factor added in the SA-CCR is translated as a different *MPOR* for the IMM: $1.5 \times 1.5 \times 10$ therefore applying the IMM margin agreement with a *MPOR* of 22.5 days would be coherent with the standardised method.

  If we chose to add only a margin agreement with daily remargining, no collateral, no threshhold, no intial margin nor minimum transferable amount, the SA-CCR *EAD* would be reduced by 67%(from the initial *EAD* 'nothing'). With the collateral addition, the SA-CCR reduces the capital charge by 76% whereas the IMM by 79% retaining the ratio between the IMM to the SA-CCR *EAD* at 70%.

- **Step 3: Netting and margin**
  As a final step we merge collateral and netting agreement to compute the capital charge. **Figure 3.13** reflects the results of all the above on the *EAD* of Portfolio 1.

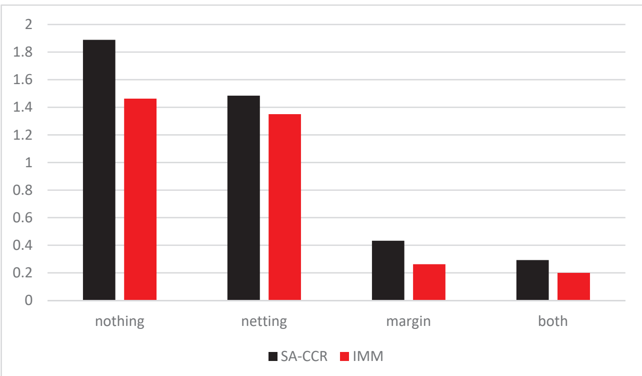

Figure 3.13: Portfolio 1 EAD

Portfolio 2

- **Step 1: Netting but no margin**
For the netting sets, SA-CCR formula for the FX class amends the absolute value of the aggregation of effective notional following:

$$\text{Effective notional} = |\text{Eff.notional}_1 + \text{Eff.notional}_2 + \text{Eff.notional}_3| \tag{3.17}$$

The internal model is less demanding than the SA-CCR in the non-netted and almost equivalent in the netted portfolios however, not by much: the netting effect is more recognized in the SA-CCR. In terms of ratios, the *EAD* decreases the standard exposure by a rate of 52% whereas it decreases the IMM *EAD* by 38%.

- **Step 2: Margin but no netting**
As for step 2, the needed modifications are put in place to recompute the *EAD* for the standardized approach. For both models, the margin agreement decreased the *EAD* (therefore the capital charge) by almost the same amount: 79% in SA-CCR and 77% in IMM.

- **Step 3: Netting and margin**
Merging collateral and netting agreement.

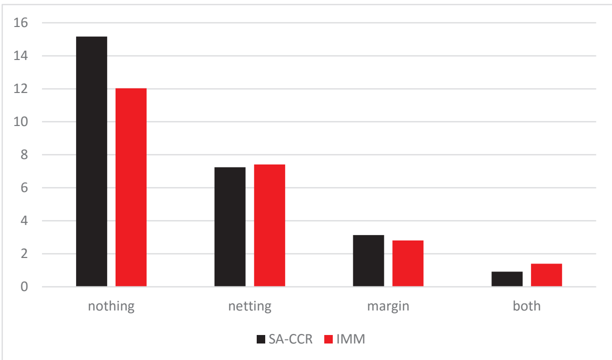

Figure 3.14: Portfolio 2 EAD

Portfolio 3

- **Step 1: Netting but no margin**
This portfolio is also in the FX bucket therefore the same computation as portfolio 2 is used in order to define the *EAD* of the whole portfolio under the SA-CCR approach. The internal model reflects the SA-CCR behavior in terms of reduction: the netting effect reduces *EAD* by 16 % in the SA-CCR and in the IMM.

- **Step 2: Margin but no netting**
For the SA-CCR the *EAD* computation results in lower *EAD*, as estimated, the collateral will amply reduce the amount of the *EAD*: 80% in SA-CCR and 81% in the IMM.

- **Step 3: Netting and margin**
Merging collateral and netting agreement in order to compute the capital charge of our portfolio.

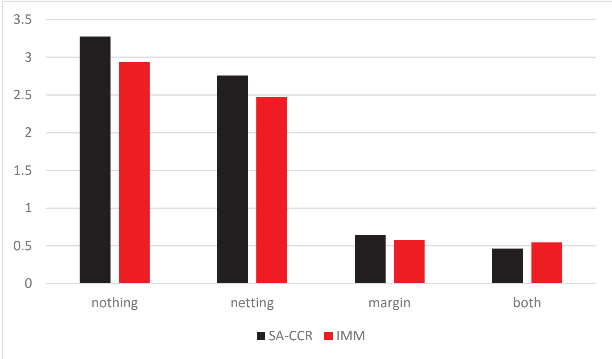

Figure 3.15: Portfolio 3 EAD

CVA capital charge

Applying Equations (3.11) to (3.14) we compute the basic CVA capital charge.We apply the computation on the previously considered portfolios: Portfolio 1, Portfolio 2 and Portfolio 3.

Considering that the counterparty we considered is a financial institution, the RW amended by Basel for this CVA approach would be 10.2%. Again not having any hedging, the CVA capital charge could be deducted as follows:

	CVA Capital Charge
Portfolio 1	0.273
Portfolio 2	1.996
Portfolio 3	0.626

Table 3.16: CVA capital charge

3.4.3 Comparative Analysis

- Default Capital Charge:
  Starting our comparison with the default capital charge section, we need to compare the IMM to the SA-CCR on the three portfolios level:
  - SA-CCR:
    Focusing on the SA-CCR we have to emphasis the importance of netting and margin agreements: The *EAD* amounts reflected in **Table 3.17** are for the standardized approach applied on the three portfolios (portfolio 1 the IR swaps, portfolio 2 the FX forwards and portfolio 3 the FX options).

	Portfolio 1	Portfolio 2	Portfolio 3
nothing	1.889	15.159	3.275
netting	1.484	7.240	2.758
margin	0.433	3.135	0.641
both	0.293	0.915	0.464

Table 3.17: EAD under the SA-CCR

Trying to make sense of these variations, the following table presents the ratios of the *EAD* for each portfolio over the *EAD* not having any collateral or netting (the ‘nothing’ case):

	Portfolio 1	Portfolio 2	Portfolio 3
nothing	100 %	100 %	100 %
netting	79 %	48 %	84 %
margin	23 %	21 %	20 %
both	15 %	6 %	14 %

Table 3.18: EAD percentage of the ‘nothing ’case

In order to interpret the results we will divide this table twice: once based on the portfolio therefore on the asset typologies, and another time based on the hedging strategies added (netting, margin agreements, none or both).

We start by discussing the results based on the asset types:
For the IR type (portfolio 1), the *EAD* decreases by 20% upon applying netting agreements: this is due to the fact that the notional amount is reduced when aggregated (Equation (3.16)) and bucketing is taken into account under the SA-CCR method. Regarding the margin additions change is due to the collateral add-ons and the maturity factors change: even if we do not add any collateral amount, having a margining agreement with daily frequency and the given threshold and MTA, the *EAD* will decrease per example in the netting case by 70% due to the change in the maturity factor. Then again adding the collateral will reduce the multiplier to less than 1 in order to reflect the collaterization effect reducing furthermore the *EAD* figure by almost 80%. When having only a collateral (and no netting), 75% reduction is observed and finally when having both hedging policies in place the reduction will increase to be 85% which is coherent with Basel suggestions that with adequate hedging techniques the capital charge could be reduced up till 90%.

The FX typology is seen in Portfolio 2 and Portfolio 3: grosso modo we can see that the impact of netting sets in this asset type is depending on the portfolios: for portfolio 2 we have three instruments where in portfolio 3 we have a strategy resembling portfolio 1 therefore the effect of netting here could be compared to the 80% observed in portfolio 1 whereas the impact is much higher for portfolio 2. One explanation of such differences might be the method of computation for the netting set effective notional on one hand (Equation (3.17)) and for the fact that in this bucket maturities are not really considered therefore this could be applied for any maturities (going form 10 days up till five years). Netting reduces the exposure to a half, and the collateral ro 20% in portfolio 2 and 80% and 20% under portfolio 3, whereas when applying both hedges the reduction is much more important hitting 95 % for Portfolio 2 and 85% for Portfolio 3.

Based on hedging techniques applied, we discuss the following:
Across all portfolios, the results of the netting techniques are various: for the first portfolio, the netting permitted a reduction of 20% whereas this reduction was far higher for the second portfolio 60% then again a 15% for the third one.

Margining also had different impacts however, having chosen to suppose a collateral that covers the 99% percentile exposure, the important reduction was the expected and homogeneous between all portfolios : an average of 80% reduction.

The last case is having both margin and netting applied, this results in a 15 % for the IR portfolio, 6% for the FX forward portfolio and 14% for the FX option portfolio.

- IMM:
  Only analyzing the internal model based on the same approach previously applied for the SA-CCR the

results are shown in **Table 3.19** in term of *EAD*:

	Portfolio 1	Portfolio 2	Portfolio 3
nothing	1.463	12.030	2.936
netting	1.354	7.413	2.473
margin	0.263	2.811	0.581
both	0.200	1.399	0.547

Table 3.19: EAD under the IMM

Making more sense of the figure, here below the same table in percentage of the non-hedged portfolios *EAD*:

	Portfolio 1	Portfolio 2	Portfolio 3
nothing	100 %	100 %	100 %
netting	93 %	62 %	84 %
margin	18 %	23 %	20 %
both	14 %	12 %	19 %

Table 3.20: EAD percentage of the ‘nothing ’case

A similar look at this table could show the differences of impact between the two assets types and the additional difference between instruments with our without optionality.

- SA-CCR vs IMM:

Comparing the IMM to SA-CCR several remarks could be presented, in order to facilitate the representation, **Table 3.21** sets the ratios of the IMM required capital to the SA-CCR required capital in the same category.

IMM/SA-CCR	Portfolio 1	Portfolio 2	Portfolio 3
nothing	77 %	79 %	90 %
netting	91 %	102 %	90 %
margin	61 %	90 %	91 %
both	68 %	153 %	118 %

Table 3.21: EAD ratio IMM/SA-CCR

Based on assets’ type, we discuss the following:

∗ Portfolio 1 shows: the IMM is less demanding than the SA-CCR in all scenarios and along with the entity of hedging techniquess. This could be interpreted by several causes: the restrictive 5% floor in the multiplier of the standardized approach or the supervisory factor of 0.5% intended to reflect the one-year volatility of the rates and which is a bit too restrictive for our USD case. In the case of margining and netting addition (when applying both techniques) the IMM always amends less capital.

∗ Portfolio 2 reflects a different ideology. Not applying neither netting nor collateral, the IMM represents 80 % of the SA-CCR *EAD*, adding the netting our IMM converges away from the SA-CCR figure (such was not the case in Portfolio 1 but here the computation of the netting sets differ in the SA-CCR) and amends similar capial requirements. When adding the margin agreement only, our model is less demanding by (representing only 90%). Last step, netting and margining the portfolio would result, in a more easy-going SA-CCR in a sort that the IMM requests the standardized capital times 1.5. This could be interpreted by the motivation given by Basel to apply such techniques therefore by the important reduction in the standardized model making the IMM much more demanding.

∗ Portfolio 3 slightly differs from the previous portfolios due to the effect of the optionality on the netting and margining computations: having the SA-CCR recommending less capital charges for optionality embedded instruments, our internal model seems to be a bit too restrictive. No hedging implies a 90% capital charge (IMM to *EAD*) and applying both methods would result in a 118%. We can deduce that for the FX options portfolio, the SA-CCR is less demanding than our internal model and requires a lower capital charge. Plus, we note that this is applied for the EUR-USD FX pair with an initial volatility of 13% in our internal models (increasing) whereas Basel amends a 15% volatility factor.

Based on hedging techniques applied, we discuss the following:

∗ When nothing is applied, on average our internal model is representing 80 % of the SA-CCR figures.

∗ Netting effects vary between portfolios depending on the composition of each one: in the IR and FX options where we net a 2.5 years by a 0.5 years instrument, the capital charge decreases by 10%. However, in the second portfolio the SA-CCR was less demanding and a ration of 102 % is observed.

∗ The margin agreement effect was more recognized in the IR swap due to the low fluctuations of such instruments (re-evaluated quarterly) making the IMM equal to only 60 % of the standardized figure. On another hand, in the FX portfolios, the fluctuations were considered through the lower and higher bonds of the margin agreement reducing more significantly the demanded capital charge (up to 90%).

∗ Finally, having both effects, Basel 'rewards' such techniques and reduces the capital in a way that makes our IMM more demanding than the SA-CCR for the FX bucket. This is expected because one purpose of this new SA-CCR is to motivate banks to margin and net their deals.

- CVA Capital Charge:

In terms of ratio, the results for the lowest possible risk weighted counterparty are presented in **Table 3.22**.

	CVA Capital Charge	CCR Capital Charge	CVA/CCR
Singular 1	35.33%	64.67%	0.54
Singular 2	35.33%	64.67%	0.54
Singular 3	35.33%	64.67%	0.54
Portfolio 1	50.40%	49.60%	1.02
Portfolio 2	56.32%	43.67%	1.29
Portfolio 3	55.87%	44.13%	1.27

Table 3.22: Capital charge Ratio of total counterparty credit risk

For the singular portfolios, having an effective maturity of one year the ratio is constant and equal approximately to 55 % to 65 % for the default counterparty capital charge therefore doubling the capital charge for the counterparty credit risk.

For the mixed portfolios, the add-on of the CVA capital charge depends on the effective maturity and the *EAD* therefore, for our considered example, the capital charge of the CVA consists of around 50% to 58% of the total counterparty capital requirement resulting in an additional 20% to 30% on the default capital charge amount amended in earlier version of Basel requirements.

3.5 Conclusion

This work permits comparison between the standardized approaches used by Basel and suggested internal model methodology based on historical and futuristic observations through various applications on simple portfolios. After having explained the aim and procedure of each required or internally suggested method the applications showed the convergence between them and highlighted the conditions were one of them is more restrictive than another.

CVA risk added a large weight to the capital requirement as expected, however its computation depends highly on the risk type that we are handling and the effective maturity of the portfolios. As for the SA-CCR, our work showed a tendency to encourage banks into hedging techniques especially margin agreements through reducing the capital charge amended when such practices are in place.

For the interest rate swap we deduct that the model chosen is less demanding than the Basel approach: On a first hand, when no hedging techniques is there, the model is representative at 80 % for such maturities (up to 2.5 years). When adding netting the percentage increases to 90 % therefore the recognition of the netting effect is much more rewarded by Basel. On the second hand, when margin agreement is in place our model requests only 60 % of Basel's capital and when netted is added the same effect as a non-margined portfolio. This is due to the computation of the margined portfolio capital charge in the interest rate bucket which includes decreasing the multiplier affecting the *EAD* resulting in reducing the total charge.

As for the foreign exchange assets types, we have different behaviors depending on the presence of optionality or not. When not handling optionality (in portfolio 2 with FX forwards), the internal model under no netting neither margin agreements represents 80 % of the *EAD* under the SA-CCR. Netting added, the internal model diverges from the standardized approach and requires 102% of the SA-CCR capital charge. Again, with no netting however adding a collateral the ratio increases to 90 % and finally when margin and netting are there the IMM *EAD* represents 150% of the SA-CCR *EAD* due to the benefits added in the Basel approach in order to reward netting and margining agreements (which is not really 'rewarded' in the Internal Model).

Handling the last portfolio, FX bucket under optionality, the conclusions differ a bit: in no netting no margin environment the IMM is a bit less demanding than the SA-CCR (by 10%) of the *EAD* this is due to the volatility factor amended by Basel (15 %) which does not reflect the volatility of the FX currency we considered (going from 14% up till 17% in GARCH approach volatility). This is permitted for the standardized approach as it tries to cover all currencies therefore could not be more indulgent in terms of amended volatility however, this might be modified a little if Basel considered assigning different volatilities for different FX currency pairs in the options types. When netting, due to the hypothesis of daily re-margin and the specificity in computing the *EAD* under the SA-CCR for optionality-included instruments, the equilibrium is not bothered and the *EAD* under both methods remains 90 %. Applying both techniques, once again Basel rewards the bank and reduces its capital requirement making the ratio of the internally amended capital charge to the standardized one equal to 118 %. Again, this is another example on how the standardized approach is rooting for the margin and netting agreements.

A model based on experts opinion and future market estimations, even if calibrated on stressed historically observed data, showed as a differing capital amendment than the one demanded by Basel. Logical interpretation could be presented and reasonable choices could be made: Basel requires a standardized fure not accounting for the currency of the instrument should be 'generalized' whereas our internal model is calibrated to the volatility, historical jumps, future forecasting... of a given market therefore in some cases could be more beneficial or more restrictive than the standardized *EAD* figure. In this paper examples on EUR and USD instruments clarified the common and different points of the two possible approaches to highlight this divergence or convergence between what banks could choose to use. In parallel, the suggested models and calibrations are a logical 'mix' between the history and the future horizons trying to create a complete figure of the market.

The last remark would be on the CVA capital charge, Basel is encouraging banks to pass the deals to central clearing houses: in doing so no CVA capital charge would be amended, after seeing the huge impact of the CVA capital charge on the total counterparty capital charge we can deduct why banks are all converging towards clearing their portfolios through trusted clearing houses, a question on the stability and coherent risk management of these clearing houses remains of high necessity in such cases.

This work aimed to offer a detailed view of the counterparty risk capital charge handling in the banking sector through a description and interpretation of the standardized amended methodologies and by presenting and contrasting an internal model that is able to reflect both historical behaviors and future expert estimations. The internal approach is mostly less demanding to banks and reflects in an enhanced way their work flow. However, we should note that our results are highly depended of the chosen portfolios and the chosen currencies. This should be noted for further work. In addition, the CVA was takled under the most basic approach without considering important risks such as the Wrong Way Risk (the correlation between the exposures and the probability of default of the counterparty). This will have an important impact on the CVA capital charge computation and in practice should not be neglected. Our next work will incorporate this variable into the computation in order to measure its impact on the CVA capital charge.

Appendices

Appendix 3.1: Supervisory Duration

In the Basel document, one component for determining the EAD of an interest rate class instrument is the supervisory duration.

In this computation we aim to understand the hypothesis lying behind the choice of such factor.

The given formula is the following:

$$SD = \frac{exp(-0.05*S) - exp(-0.05*E)}{0.05} \tag{3.18}$$

If we consider a bond with a staring date S and an ending date E, paying coupons of rate α and having a yield to maturity YTM equal to α; the valuation of this bond's duration in a continuous fashion will result in the following:

$$Duration = [\frac{\int_0^{E-S} \alpha t \exp^{-\alpha t} dt + (E-S)\exp^{-\alpha(E-S)}}{\int_0^{E-S} \alpha \exp^{-\alpha t} dt + \exp^{-\alpha(E-S)}}] \times \exp^{-\alpha S}$$

Using an integration by parts process, the previous equation results in the following:

$$\begin{aligned}
Duration &= \frac{[-t\exp^{-\alpha t}]_0^{E-S} + \int_0^{E-S} \exp^{-\alpha t} + (E-S)\exp^{-\alpha(E-S)}}{-[\exp^{-\alpha t}]_0^{E-S} + \exp^{-\alpha(E-S)}} \\
&= \frac{(-(E-S)\exp^{-\alpha(E-S)}) - \frac{1}{\alpha} \times (-\exp^{-\alpha 0} + \exp^{-\alpha(E-S)}) + (E-S)\exp^{-\alpha(E-S)}}{\alpha \exp^{\alpha S}} \\
&= \frac{1 - \exp^{-\alpha(E-S)}}{\alpha \exp^{\alpha S}} \\
&= \frac{exp(-\alpha * S) - exp(-\alpha * E)}{\alpha}
\end{aligned}$$

Replacing the α factor by 0.05 or 5 % we obtain the supervisory duration in Basel.

The duration is an indication of the instrumetns's maturity because the maturity is capped at one year, therefore the necessity of the incorporation of that factor.

Appendix 3.2: Data used

The data sets are extracted from Bloomberg on the EUR, USD swaps, and the FX rates USD/EUR. The time period is from April 2000 until December 2015.

We can observe the 3m, 1y and 5y rates along major crisis: 2000-2001 Early 2000s recession affecting European Union, 2001 September The attack on World Trade Center, 2002 January The introduction of the EURO 2002-2003 Early 2000s recession affects the US, 2007-2010 The Financial Crisis and the most recent Europe debt crisis.

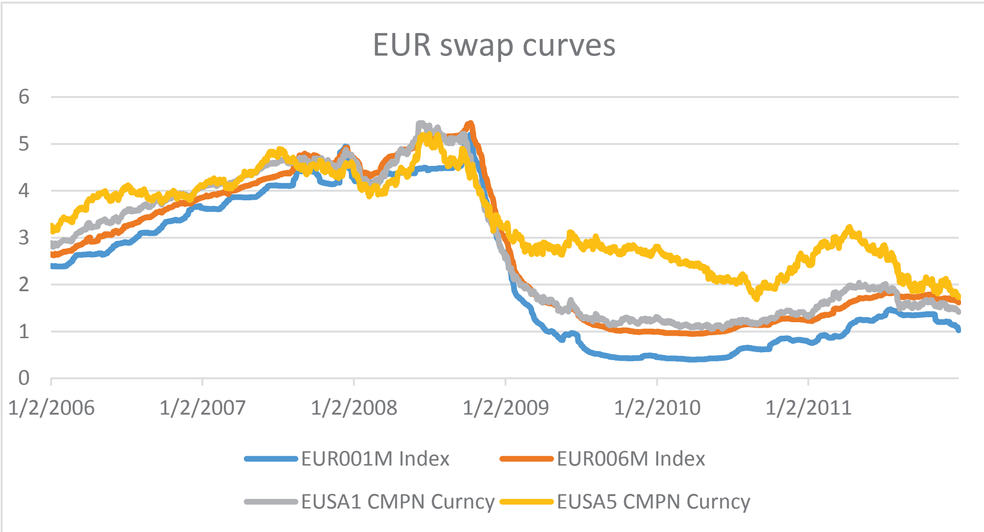

Figure 3.16: Historical Euro swap rates for 1m, 6m, 1y and 5y

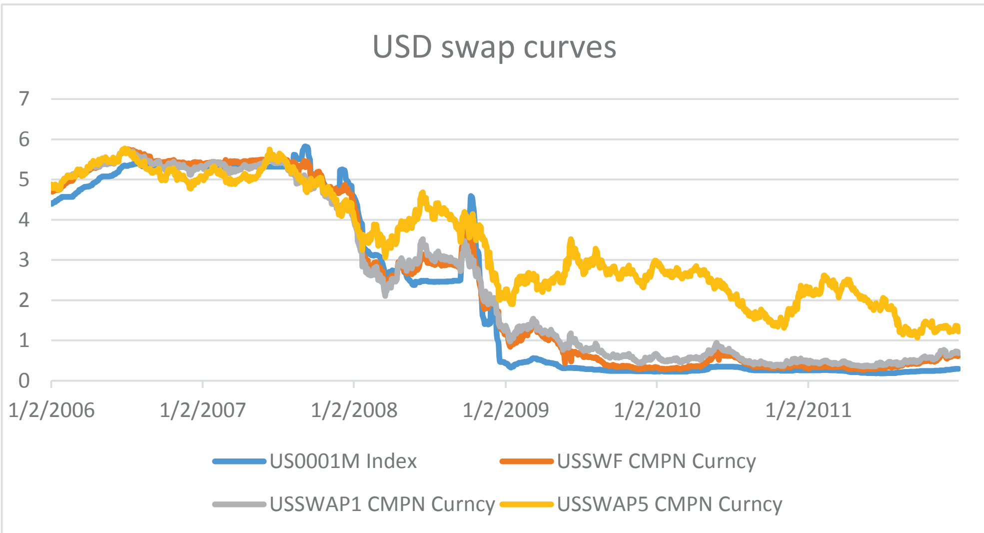

Figure 3.17: Historical USD swap rates for 1m, 6m, 1y and 5y

FX rates are also extracted from Bloomberg and reflects the same issues along with the political conditions of those periods:

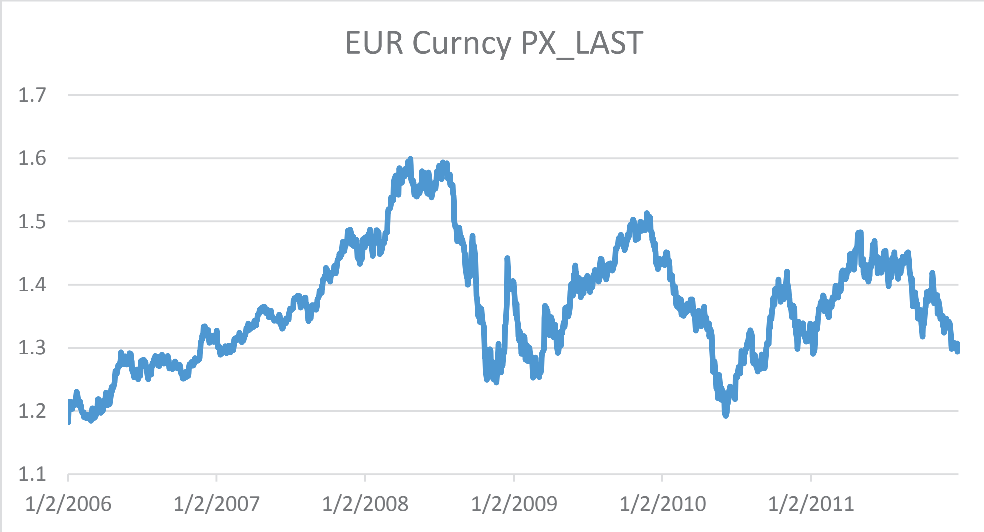

Figure 3.18: Historical FX spot rate

Appendix 3.3: Vasicek model implementation

The work on Vasicek model was based on the paper by Planchet and Karam (2013):

Vasicek discretization formula:

$$r_{t+\delta} = r_t e^{-k\delta} + \theta(1 - e^{-k\delta}) + \sigma\sqrt{\frac{1 - e^{-2k\delta}}{2k}}\varepsilon_k$$

Estimating the parameters:

$$\hat{k} = -\frac{1}{\delta} ln(\hat{\beta})$$

$$\hat{\beta} = \frac{n\sum_{i=1}^{n} r_i r_{i-1} - \sum_{i=1}^{n} r_i \sum_{i=1}^{n} r_{i-1}}{n\sum_{i=1}^{n} r_{i-1}^2 - (\sum_{i=1}^{n} r_{i-1})^2}$$

$$\hat{\theta} = \frac{\sum_{i=1}^{n}[r_i - \hat{\beta} r_{i-1}]}{n(1 - \hat{\beta})}$$

$$\hat{\sigma} = \sqrt{\frac{\frac{1}{n}\sum_{i=1}^{n}[r_i - \hat{\beta} r_{i-1} - \hat{\theta}(1 - \hat{\beta})]^2}{\frac{1-e^{-2k\delta}}{2k}}}$$

$$\lambda = ((\theta - \frac{\sigma^2}{2k^2}) - (\frac{(\frac{\sigma^2}{4k}B(0,T) + r_0)B(0,T) + ln(P(0,T))}{B(0,T) - T}))\frac{k}{\sigma}$$

And getting the yield we apply the following:

$$R(t,T) = -\frac{ln(P(t,T))}{T - t}$$

$$P(t,T) = A(t,T)e^{-B(t,T)r(t)}$$

$$A(t,T) = exp[(\theta - \frac{\sigma\lambda}{k} - \frac{\sigma^2}{2k^2})(B(t,T) - (T - t)) - \frac{\sigma^2}{4k}B(t,T)^2]$$

$$B(t,T) = \frac{1 - e^{-k(T-t)}}{k}$$

Appendix 3.4: GARCH Model parameters

The Garch(1,1) model is given by these formulas:

$$\sigma_t = \sqrt{a_0 + a_1 r_{t-1} + b_1 \sigma_{t-1}}$$
$$r_t = \sigma_t \varepsilon_t$$

where ε_t is random normal variable.

Garch(1,1) normal conditions:

```
Call:
garch(x = Y, order = c(1, 1), include.intercept = FALSE)

Model:
GARCH(1,1)

Residuals:
     Min       1Q   Median       3Q      Max 
-5.20660 -0.61305  0.01523  0.61162  6.64918 

Coefficient(s):
    Estimate  Std. Error  t value Pr(>|t|)    
a0 1.570e-07   3.289e-08    4.773 1.82e-06 ***
a1 3.964e-02   2.922e-03   13.566  < 2e-16 ***
b1 9.577e-01   3.052e-03  313.838  < 2e-16 ***
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Diagnostic Tests:
 Jarque Bera Test

data:  Residuals
X-squared = 343.7085, df = 2, p-value < 2.2e-16


 Box-Ljung test

data:  Squared.Residuals
X-squared = 10.8817, df = 1, p-value = 0.0009712
```

Garch(1,1) stressed conditions:

```
Call:
garch(x = Y, order = c(1, 1), include.intercept = FALSE)

Model:
GARCH(1,1)

Residuals:
     Min       1Q   Median       3Q      Max 
-5.11002 -0.59314  0.02417  0.63419  6.55395 

Coefficient(s):
    Estimate  Std. Error  t value Pr(>|t|)    
a0 2.193e-07   8.016e-08    2.736  0.00622 ** 
a1 4.054e-02   3.441e-03   11.782  < 2e-16 ***
b1 9.560e-01   3.907e-03  244.730  < 2e-16 ***
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Diagnostic Tests:
 Jarque Bera Test

data:  Residuals
X-squared = 202.9086, df = 2, p-value < 2.2e-16


 Box-Ljung test

data:  Squared.Residuals
X-squared = 12.3976, df = 1, p-value = 0.0004299
```

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Chapter 4

Basel III Credit Valuation Adjustment Capital Charge and Wrong Way Risk

Basel regulations are encouraging the shift to central clearing of derivatives products in order to make these instruments market more transparent and regulated. However, for those non-cleared derivatives Credit Valuation Adjustment (CVA) capital charge is amended. In this work, a first part explains the newly proposed approaches for computing the regulatory CVA capital requirement. Afterwards, the importance of incorporating the Wrong Way Risk (WWR) in the computation of the CVA is detailed. An approach based on Error Correction Models highlights the differing impact of such risk for several counterparties. Applications on interest rate swaps with a single investment grade sovereign counterparty are considered. A first conclusion discusses the divergence between the two regulatory approaches when dealing with different counterparties within the same risk bucket. In addition, another result is interpreted following the ECM methods reflecting the changing impact of the WWR for the counterparties considered: even for the three European investment grade sovereigns, the model reflected a higher WWR for Spain than the one observed for Ireland or France. A proposed modified scale for Basel methodologies would account for the effective credit quality and WWR of each specific counterparty in a way that converges the requested charge under both possible regulatory capital charge methodologies.

Keywords: *CVA, WWR, ECM, Basel III, BA-CVA, FRTB SA-CVA.*

4.1 Introduction

Several reforms were based on the 2007-2008 financial crisis especially in the risk management field through banks regulators. The incomplete assessment of existing risks led banks into major problems and induced severe losses. Counterparty risk played a major role in these implications. Starting with the collapse of Lehman Brothers and several near or full collapses of banks all over the United States, United Kingdom and Europe, the counterparty risk gained now the same importance as the major well-known risks (market, liquidity, operational). Counterparty credit risk is of central need in several areas of the banking work-flow: pricing Over The Counter (OTC) products, computing the capital charges, managing exposures to different counterparties and finally stating the conditions of a certain deal concerning the initial agreed-upon margin or collateral (cf. Ruiz, 2013).

OTC derivatives trading is a rapidly growing activity: OTC derivative transactions notional amounts increased from 90 trillion USD in 2000 to 670 trillion USD in 2008 this widened banks' exposure on OTC derivatives and potential losses became sufficiently important not to be denied (cf. BIS, 2012). Based on the above, OTC derivatives are mostly concerned with this kind of risk therefore regulators are changing and adding new methodologies for computing the counterparty risk and covering all its aspects notably in Basel, IFRS 13 and FAS 157. Initially, counterparty risk capital charge was introduced in Basel II to cover the default risk (using current exposure method), refer to Cespedes et al. (2010) for a detailed interpretation of the standardized counterparty credit risk modeling in Basel II framework. In Basel III, two modifications are in place: the computing methodology of the default risk is modified (cf. BCBS, 2014) and a new capital charge was added to the counterparty risk: the Credit Valuation Adjustment (CVA) risk capital charge (cf. BCBS, 2011). The probability of devaluation of counterparties once neglected, is highlighted and accounted for in the most recent regulatory frameworks denoted as CVA capital charge.

Regulators amended a way to compute the CVA capital charge: in 2010, Basel III proposed a standardized and an internal approach for computing the CVA regulatory capital (cf. BCBS, 2010) and in 2015 a consultative document suggested two frameworks: a basic formula approach and a FRTB-CVA methodology: a standardized and an internal approach (cf. BCBS, 2016 (b)). Although it was implemented in 2010, Basel III regulatory framework only becomes effective starting a rolling window between the years 2013 and 2019. On a side note, we should note the slight divergence between EU and US approaches for the CVA capital charge implementations (cf. Reynolds et al., 2013).

CVA being the market price of credit risk beard in the instrument, it could be simply represented as the difference between the discounted value of the derivative and its discounted value including the counterparty valuation risk. Therefore, the Credit Valuation Adjustment requires the computation of not only the future exposure but also the probability of default of the concerned counterparty and the amount the bank is expecting to loss (or recover) in case of counterparty's default. Indeed, CVA depends on the Loss Given default (LGD), the probability of default (PD) and the expected exposure (EE). The PD is the financial term describing the likelihood of a default over a particular time horizon, EE is the total value a bank is exposed to at a given time (the average of the maximum between 0 and the MtM) and LGD is the percentage which is expected to be lost if the counterparty defaults.

These three elements are highly correlated however, several works did not take this correlation into account whereas other papers incorporated its impact under the nomenclature of the 'Wrong Way Risk'. The Wrong Way Risk (WWR) is the impact encountered in the CVA due to the negative correlation between the PD and the EAD: if an increase of exposure would result in an increase of probability of default, WWR is faced. According to ISDA (cf. ISDA, 2003), 'WWR occurs when exposure to a counterparty is adversely correlated with the credit quality of that counterparty. Wrong Way Risk, as an additional source of risk, is rightly of concern to banks and regulators'.

Calculating CVA without WWR is common 'academic' protocol, see Gregory (2011), however in practice, letting the WWR unaccounted for could be significantly underestimating the risk. Among practitioners two methodologies are being used to compute the CVA figure with or without inclusion of the WWR: simulations (Monte Carlo processes) or Copula formulas incorporating the market-credit correlation.

This present work aims to understand Basel requirements in terms of CVA capital charge and compare both of the capital requirement methods suggested by Basel III in the case of an investment grade sovereign counterparty: using the Basic approach, a simple formula application would be in place whereas for the FRTB-CVA a sensitivity computation should be held. This computation needs to incorporate the WWR, therefore a Monte Carlo simulation approach based on Error Correction Models is used to reflect the impact of the exposure movement on the credit spread of the counterparty. Applications on interest rate swaps held with the French, Irish and Spanish sovereigns show differing results in terms of CVA sensitivity in the same counterparty bucket leading to a proposal for a different coefficient scaling in the Basel III CVA framework.

The flow will be divided as follows: Section 1 describes the CVA framework in the banking sector, Section 2 introduces the regulatory framework of the most recent CVA capital charge under Basel III with a quick comparison between the most recent Basel publications on that subject. Section 3 explains the computation of the CVA figure. Section 4 proposes the chosen mathematical approach to compute the CVA sensitivity under the FRTB approach with details of the models used, Section 5 applies these approaches to market data in order to compute several CVA figures and compare them among different counterparties. After doing so a scaling of Basel coefficients is proposed. Finally, a conclusion highlights the purpose of this work and its main results.

4.2 Credit Valuation Adjustment

According to Gregory: 'the risky price of a derivative can be thought of as the risk-free price (the price assuming no counterparty risk) less a component to correct for counterparty risk. The latter component is often called CVA, Credit Valuation Adjustment'. In simpler terms, the CVA is the price we are paying for the risk handled in this given instrument.

The CVA might be considered as a unilateral component or a bilateral one: the unilateral CVA assumes that the bank computing its own capital charge is risk free and would not default whereas a bilateral CVA computation would consider both counterparties default probability. Logically, and to be the most representative of the market we are in, a bilateral CVA should be computed however in the Basel computation only unilateral case is considered therefore in the rest of this paper we are going to consider the unilateral CVA, referred to as CVA.

Consider a constant recovery rate R (non dependent from neither the exposure nor the counterparty credit quality), the main equation representing the CVA at time $t = 0$ is:

$$\text{CVA} = (1-R)E[V^+(\tau)1_{\tau \preceq T}] \tag{4.1}$$

where

- τ is the time of default
- $V^+(\tau)$ is the positive discounted value of the MtM at time τ
- T is the longest maturity in the portfolio
- $1_{\tau \preceq T}$ is the indicator function equal to 1 if the counterparty defaults before T and null if the counterparty does not default.

However, under no WWR assumption and as briefly explained in the introduction, CVA is the product of three components: Loss Given default (LGD), Expected Exposures (EE) and Default Probabilities (PD). LGD is the unit minus the recovery rate $(1-R)$. The expected exposures are computed as the positive values of the instruments exposure after having simulated the different risk factors in place into the future and evaluating the instrument. Discounting factors are used to discount all exposures to the current time of computation. Default probability represents the probability of defaulting in a given time interval considered between inception and maturity.

One way of writing the CVA formula, assuming no correlation between the exposure and the probability of default, and having divided the time between 0 and the maturity into m equivalent intervals is represented below:

$$\text{CVA} = LGD \sum_{j=1}^{m} EE(t_j^*)DF(t_j^*)PD(t_{j-1}, t_j) \tag{4.2}$$

where

- $t_j = \frac{j}{m}T$ and t_j^* is the midpoint of the interval $[t_{j-1}, t_j]$
- $EE(t_j^*)$ is the expected exposure at time t_j^*
- $DF(t_j^*)$ is the discounting factor from time t_j^* to the initial time 0
- $PD(t_{j-1}, t_j)$ is the probability of default between times t_{j-1} and t_j, i.e

$$PD(t_{j-1}, t_j) = P(t_{j-1} \leqslant \tau \leqslant t_j).$$

One important feature of the CVA computation is that it combines figures from several sources in the banks: EE is part of the market risk, LGD and PD figures are the responsibility of the credit risk team whereas the trading desk may provide the risk-free discounting factors. This emphasizes the highlighted issue by Basel that demands independent CVA desks to be responsible for this task.

In this work, we focus on the CVA for interest rate swaps. The expected exposure of an interest rate swap can be seen as the value of a swaption. It is therefore clear that pricing CVA is more difficult than pricing the swap itself. While the risk-free pricing of a swap depends only on current market interest rates the CVA value adjustment of a swap also depends on market volatility (cf. Skoglund and Chen, 2015) based on the fact that we can see the CVA as a derivatives price. Therefore, the volatility component of the models used in order to compute the exposure are fitted to traded instruments on the market such as swaptions or caplets in order to stay in a risk-neutral calibration.

Wrong Way Risk and CVA

Previous equation showed the CVA figure under a widely used assumption: the independence between the exposure and the credit quality. However, on the market this is not the case. Murphy's law states that anything that CAN go wrong WILL go wrong, and it is human nature to tend to assume that things will converge to the wrong way rather than the other way. This is the case on the derivatives market: for example, Duffee (1996) shows a clustering of corporate defaults in the US during periods of falling interest rates. This would suggest that a receiver (payer) interest rate swap should have Wrong-Way (Right-Way) Risk.

Wrong Way Risk is the 'bad' dependence between exposure and counterparty credit quality: when a bank is highly exposed to a counterparty and its credit quality declines instead of potentially loosing an amount X the bank will be exposed to a greater amount. Not to be very pessimistic, if this WWR is possible another right way risk might be present too, however in this case it would be in favor of the bank so it will not threaten the banks' sufficient capitals.

Considering the case of interest rate swaps, we need to study the behavior of the CDS and swap all together to see if the counterparty default risk is higher in high or low interest rate environments. In the first case per example, payer swaps with the counterparty have WWR and receiver swaps have right-way risk.

The most simple way of incorporating WWR into the CVA computation is to use a certain buffer: consider that the exposure under WWR is equal to the one under no WWR multiplied by a given coefficient. Basel uses this approach to account for the WWR by using a multiplier alpha equal to 1.4. Different methodologies can be seen in literature on how to change the exposure or how to incorporate the WWR effect in the exposure component.

However in their work, Hull and White (2012) proposed an approach to incorporate the WWR into CVA without changing the Monte Carlo exposure simulations and just incorporating it in the hazard rate: Instead of recomputing the exposures, they recomputed the probability of default depending on variables that impacts the exposure in the Monte Carlo simulations. Introducing the concept of the hazard rate, Hull and White proposed modeling the link between this probability of default in a infinitesimally small time interval to different variables that affect the exposure. Proposed ideas for these variables were: the value of the dealer's portfolio with the counterparty, the value of the factor that impacts the counterparty's well-being such as the price of the commodities he is dealing with or the exchange rate, and finally a given credit-spread could be chosen to be this variable in order to reflect the relationship on the counterparty's health. As an application in their article (cf. Hull and White, 2012), they linked the hazard rate to the value of the portfolio: an exponential function is used to link and then estimate the hazard rate and the portfolio exposure in order to get the impact of the WWR. Their paper highlighted the major effect of the WWR on CVA and found the percentage effect dependent on the collateral agreement related to the instruments. Bavaria et al. (2015) added to Hull's paper the incorporation of path dependency when calibrating the time dependent model. In the literature few papers used finite difference Monte Carlo such as De Graaf et al (2014) to estimate the CVA figure with less computational cost however neglected the inter-dependencies.

Other approaches were to incorporate copulas to illustrate the dependency between the default time and underlying market factor. An example is, Cerny and Witzany paper where they constructed a semi-analytical formula computing the CVA with and without WWR for interest rate swaps (2013) using a Gaussian copula then estimated their model parameters based on the market data (cf. Cerny and Witzany, 2014). However, the Gaussian distribution does not reflect the market adequately, therefore, they extended their previous work on the interest rate swaps using Frechet copulas (Cerny and Witzany, 2015) but still only using one constant correlation between the default time and the interest rates. A full literature review of the methodologies used by practitioners to compute the WWR under the CVA framework could be found in Ruiz consultancy document (cf. Ruiz, 2013): regulatory choices and mathematical models used by banks. All such models have several pros and cons but the main issue is the large number of assumptions to be put in place in order to get the CVA figure such as the loss given default, the copula chosen for the dependence and the correlation coefficient taken into account.

4.3 CVA capital requirement under Basel

In the Basel III framework, the CVA capital charge amendment was one major change. A standard formula was introduced with the possibility of computing this capital charge based on an internal approach. More recently, in July 2015 (cf. BCBS, 2015) the banking committee of Basel proposed new approaches for the CVA capital charge computation in a consultative document which are inspired by the fundamental review of the trading book: sensitivity is the key. The proposed approaches are three: under the FRTB framework we have two methods: the standardized (SA-CVA) and the internally implemented (IMM-CVA) and the third method is one were all banks are eligible: the basic CVA approach (BA-CVA).

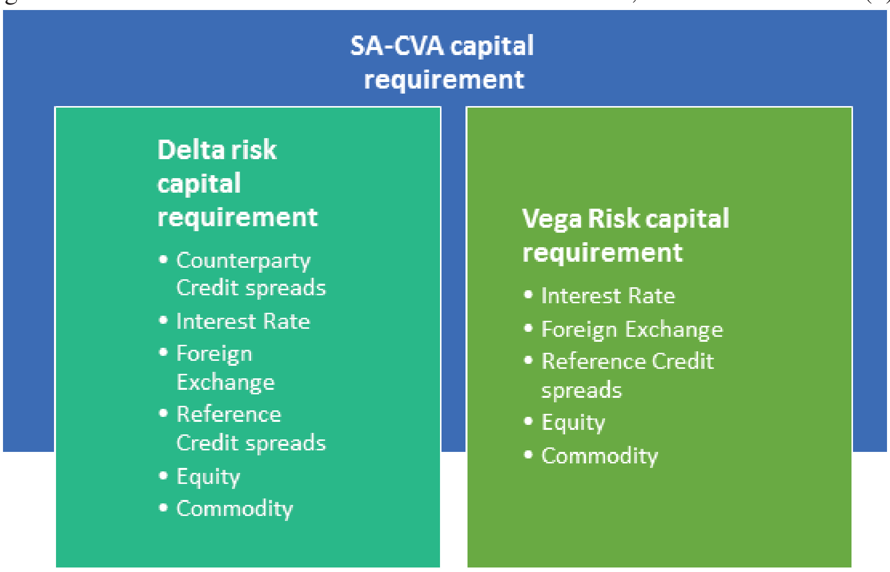
The rationale behind these changes to the CVA framework are summarized by the BCBS as follows: to better capture all CVA risks and better recognize CVA hedging techniques, align industry practices (more specifically alignment with the IFRS 13 regulations) and finally alignment with the proposed changes in the market risk framework (FRTB). However, after suspecting potential 'mysterious processes' in the internal model construction, Basel demanded the elimination of the IMM-CVA in his review of internal modeling (cf. BCBS, 2016(a)) and changed the coefficient used in the remaining two methods under its QIS for the CVA (cf. BCBS, 2016(b)) leaving banks with two possible methods for the CVA capital charge computation: SA FRTB-CVA and BA-CVA.

4.3.1 FRTB SA-CVA

The SA-CVA is similar to the standardized trading book approach (SA-TB) (cf. BCBS, 2016 (c)). The main differences between these two methods are the reduced granularity in the CVA approach, and the presence of a multiplier $m = 1.5$. In the consultative document, the multiplier of 1.5, is justified by Basel as to fill for the missing granularity in this framework, to compensate for model error and could be increase if no adequate WWR consideration is taken into account when computing the sensitivities.

Note that in the remainder of this paper we are discussing two main Basel documents: the consultative document of July 2015 (cf. BCBS, 2015b), and the QIS proposed in February 2016 (cf. BCBS, 2016b) that changed few weights and amended that the multiplier of 1.5 is not to be used for the FRTB-SA CVA approach reducing it to 1). All figures in the appendixes are based on the recent QIS proposition. The repartition of the risk factors for each capital requirement is summarized in the following diagram:

Figure 4.1: Division of the risk factors in the FRTB SA-CVA, source: BCBS 2016 (b)



The Delta and Vega computation is needed for different types of risk. A similar approach is used for both: for a given type, the steps are as follows:

1. Divide the instruments into risk types.
2. Divide the risk types into buckets (refer to Table 13 in Appendix A).
3. Compute the sensitivity of the aggregated CVA.
4. Compute the sensitivity of all eligible hedges (for a detailed list of eligible hedges ref to Sayah, 2016).
5. Obtain the weighted sensitivities for each risk factor by multiplying the sensitivities by the given risk weights (refer to Table 14 in Appendix A).
6. The net weighted sensitivity is the sum of both weighted sensitivities: instruments and their hedges.
7. Aggregate these weighted sensitivities into a bucket capital charge using the correspondent correlation parameters (refer to Table 15 in Appendix A for correlations in a given bucket).
8. Aggregate all buckets to get a capital charge for each risk type (Refer to Table 16 in Appendix A for cross-bucket correlation parameters).

Risk types capital requirement simple sum results either in Vega or in Delta risk requirement, the sum of which, multiplied by the amended multiplier, gives the SA-CVA total capital requirement.

Two options are permissible in the Basel framework for conditions applying on the CVA: Accounting CVA and internal model based CVA. In the following, we will work with the accounting CVA for consistency between front office and capital charge computation on one side and due to the fact that we need approval from supervisory authority to use the internal model method for the exposure computation.

4.3.2 Basic CVA

Not having all banks granted a supervisory approval to apply the FRTB-CVA standardized approach cited earlier, another framework is necessary for the remaining banks: the basic CVA approach. Conditions on eligible hedges could be found in my previous work (cf. Sayah, 2016). The basic approach presents one formula that computes directly the CVA capital charge based on a spread and an exposure component. The computation accounts for hedged and unhedged CVA risks and is based on a Gaussian copula assuming a correlation of 50% between systematic and idiosyncratic risk factors, an exposure capital equal to 0.5 of the spread component and on risk weights depending on the rating of the counterparty (not the granular rating but a grade classification: investment grade or non-investment grade). Taking these assumptions into account, the formula computes the capital as the expected shortfall on a 97.5% confidence level and one-year time horizon.

Assuming that our portfolio is not hedged for the CVA risk which is the case in the majority of smaller banks, the formula for the capital charge given by BA-CVA is the following:

$$K_{CVA}^{unhedged} = K_{EE} + K_{Spread} = 1.5 \times K_{Spread} \tag{4.3}$$

where

$$K_{Spread} = \sqrt{(\rho \sum_c S_c)^2 + (1-\rho^2) \sum_c S_c^2} \tag{4.4}$$

and

$$S_c = \frac{RW_{b(c)}}{\alpha} \sum_{NS(c) \in c} M_{NS} EAD_{NS(c)} \tag{4.5}$$

with

- c is a counterparty
- $NS(c)$ the netting set of the counterparty c
- M the effective maturity

- ρ the 50% correlation term
- *EAD* the exposure at default computed using the same approach as for default risk. In this paper, we consider the Standardized Approach for Counterparty Credit risk (SA-CCR) to compute this figure (cf. BCBS, 2014))
- α the factor that converts EEPE to EAD equal to 1.4 under both IMM and standardized approaches
- $RW_{b(c)}$ the risk weight for the counterparty given by Table 1 (for our chosen accounting CVA option)

	Investment Grade	Non Investment Grade
Sovereigns including central banks, multilateral development banks	0.5%	3.0%
Local government, government-backed non financials, education and public administration	1.0%	4.0%
Financials including government-backed financials	5.0%	12.0%
Basic materials, energy, industrials, agriculture, manufacturing, mining and quarrying	3.0%	7.0%
Consumer goods, services, transportation, storage, administrative and support service activities	3.0%	8.5%
Technology, telecommunications	2.0%	5.5%
Health care, utilities, professional and technical activities	1.5%	5.0%

Table 4.1: Supervisory Risk Weights for BA-CVA, Source: QIS instructions 2016, BCBS

We highlight that important differences in these risk weights can be observed between the consultative document and the QIS: After the publication of the consultative document, banks commented on the overly conservative aspect of the new approaches notably the BA-CVA therefore in the QIS suggestions the weights were reduced at least to a half. One major change is observed in the sovereign bucket risk weight were the 2016 QIS 0.5% observed was an 8.8% coefficient in the consultative document in 2015.

4.4 Credit Valuation Adjustment computation

Considering a fix payer interest rate swap we need to compute the CVA of such instrument: two cases are presented: to account for the WWR or not to.

Based on Gregory's book (2011), CVA at time $t = 0$ can be written as follows:

$$\text{CVA} = (1-R)E^{Q}[1_{\tau \preceq T} V(\tau, T)^{+}] \tag{4.6}$$

where

- R is the recovery rate considered independent from the exposure and the default probability
- τ is the time to default
- T is the longest maturity in the derivatives portfolio
- Q is the risk neutral probability
- $V(\tau, T)^{+}$ the positive discounted value for a maturity T and a time of default τ.

We note X the risk factor of the instrument considered: in our case $X_T = (s_1, s_2, ..., s_T)$ the swap rates at each tenor and $V(\tau, T, X_T)^{+}$ is the present value of the positive exposure that depends on the risk factor X_T, the maturity T and the time of default τ.

The resulting CVA equation would be:

$$\text{CVA} = (1-R)E^Q[1_{\tau \preceq T} V(\tau, T, X_T)^+] \tag{4.7}$$

For a fixed payer interest rate swap with fixed coupon K, this V for a given τ could be seen as the present value of a swaption with maturity T and exercise date τ (Notional is considered 1). Discretising our equation, we divide the time interval into m equivalent intervals. For our considered interest rate payer swap with semi-annual coupons and repricing frequency, the discounted positive exposure is given by (cf. Hull, 2006, p.137):

$$V(t_{i^*}, T, X_T)^+ = \max\left(0, (1 + fr \times s_i) \times DF_{t_{i+1}, t_{i^*}}(X_T) - K \times fr \times \sum_{j=i+1}^{m} DF_{t_j, t_{i^*}}(X_T) - DF_{t_m, t_{i^*}}(X_T)\right) \times DF_{t_{i^*}, t_0} \tag{4.8}$$

where

- fr is the payment frequency equals to 0.5 if we consider semi-annual payments
- $t_i = \frac{i}{m}T$ being the different repricing dates (each 6 months)
- t_{i^*} is the midpoint of the i^{th} interval
- s_i is the short rate at the most recent previous repricing date
- $DF_{t_k, t_j}(X_T)$ is the discounting factor at time t_k to time t_j computed based on the swap rates structure

Resulting in:

$$\text{CVA} \approx (1-R)\sum_{i=1}^{m} E^Q[1_{t_{i-1} \preceq \tau \preceq t_i} V(t_i^*, T, X_T)^+] \tag{4.9}$$

where t_i^* is the midpoint of the i^{th} interval. Conditioning on the risk factor X_T results in the following:

$$\text{CVA} = (1-R)\sum_{i=1}^{m} E_X^Q[E^Q(1_{t_{i-1} \preceq \tau \preceq t_i} V(t_i^*, T, X_T)^+ | X_T)]$$

$$\text{CVA} = (1-R)\sum_{i=1}^{m} E_X^Q[V(t_i^*, T, X_T)^+ E^Q(1_{t_{i-1} \preceq \tau \preceq t_i} | X_T)]$$

$$\text{CVA} = (1-R)\sum_{i=1}^{m} E_X^Q[V(t_i^*, T, X_T)^+ P(t_{i-1} \preceq \tau \preceq t_i | X_T)] \tag{4.10}$$

If the exposure and the time of default are independent, the conditional probability is equal to the unconditional probability therefore our equation will be:

$$\text{CVA} = (1-R)\sum_{i=1}^{m} E_X^Q[V(t_i^*, T, X_T)^+] P(t_{i-1} \preceq \tau \preceq t_i) \tag{4.11}$$

Market practice frequently consider the survival probability to be of an exponential distribution of a constant parameter h known as the hazard rate. The hazard rate measures the probability that a default will occur: the probability that a default will occur within any short period of time Δt, conditional on no earlier default, is $h\Delta t$. (cf. Hull and White, 2012). This parameter can not be observed however, it could be approximated by the CDS spreads: the hazard rate between time 0 and time t is $\frac{s(t)}{1-R}$ where $s(t)$ is the credit spread for a maturity of t.

Therefore, the default probability between two time points can be estimated using the CDS spreads s as follows :

$$P(t_{i-1} \preceq \tau \preceq t_i) = \exp\left(-\frac{s_{i-1}t_{i-1}}{1-R}\right) - \exp\left(-\frac{s_i t_i}{1-R}\right) := q_i \tag{4.12}$$

The resulting CVA would be:

$$\text{CVA} = (1-R)\sum_{i=1}^{m} E_X^Q[V(t_i^*, T, X_T)^+] q_i. \tag{4.13}$$

Or in the IRS case:

$$\text{CVA} = (1-R)\sum_{i=1}^{m} V_{swaption}(t_i^*, T)q_i. \tag{4.14}$$

where the value of the swaption is the average of the values computed in Equation (4.9) over all simulated risk factors paths.
Note that this result matches Hull and White 2012:

$$\text{CVA} = (1-R)\sum_i v_i q_i.$$

4.5 Methodology: Computing the CVA figures and incorporating the WWR through Error Correction Models

The purpose of this work is to compare the two Basel proposed methodologies for computing the CVA capital charge in a given condition: Interest Rate Swap (IRS) portfolios with an investment grade sovereign counterparty.

For the BA-CVA we need to apply regulatory formulas whereas for the FRTB-SA CVA approach a computation of the CVA figure is a must in order to generate the sensitivities. Under the most global conditions, Equation (4.10) proves that the simulation of both terms (the exposure and the probability of default) under Monte Carlo processes is a must (not having a closed form formula). Therefore, a model estimating each under a risk neutral probability should be considered. In this paper, the Hull and White interest rate model is used to project the swap rates and deduce the exposures. Error Correction Models (ECM) are used to reflect the behavior dependency between the swap rates and the CDS spreads resulting in the probability of default.

In order to reach our aim, the steps of the methodology can be resumed as such:

1. For a given date (set as $t = 0$) get the data from the market: CDS spread curves and swap rates.
2. After having calibrated the Hull and White one factor interest rate model under a risk neutral probability based on observed market swaption prices, we use it to generate future swap rates (therefore exposures). Details can be found in Section 4.4.1.
3. Using present CDS curves and simulated exposures, we compute the CVA at $t = 0$ without taking into account the WWR as seen in Equation (4.13).
4. In order to incorporate the WWR, we use Error Correction Models: We start by estimating historically, a separate model for each maturity linking the swap rates and the CDS spreads. In order to move from the historical probability to the risk neutral world, we assumed that the ECM can be applied however the resulting CDS spreads are modified in order to reflect no arbitrage opportunities. Details of the computation and assumptions can be found in Section 4.4.2.
5. The usual way of modeling the WWR is to reflect it in the simulated exposure (ex: multiply the exposure by a given coefficient). Based on Hull and White (2012) idea of reflecting the WWR by changing the probability of default (conditionally to the simulated exposures) instead of changing the exposure, we recompute the new WWR including CVA figure after having simulated the CDS curves following Equation (4.10).
6. Having the CVA number, we compute the CVA capital charge based on sensitivities for the SA-FRTB CVA and following the BA-CVA formula compute its given capital charge.
7. Compare both approaches for one given counterparty.
8. Compare the results for three different investment grade sovereigns counterparties.
9. Suggest a calibration of the risk weights mainly used in the basic approach to be more reflective of the specific risk encountered by each counterparty.

4.5.1 Hull and White one factor interest rate Model

A full review on interest rate models can be found in Brigo and Mercurio's book (2006). From one factor to multi-factors models, a wide variety of interest rate models are being used by practitioners on the market. One famous approach is the Hull and White model.

In a risk neutral world denoted $\mathbb{Q}$, the Hull and White short rate model is defined as follows:

$$dr(t) = \Big(\theta(t) - a(t)r(t)\Big)dt + \sigma(t)dW^{\mathbb{Q}}(t) \tag{4.15}$$

where

- $\theta(t)$ is the function that permits the exact replication of the initial yield curve (this is a major benefit of this model compared to others such as Vasicek Model). Equation (4.19) details the computation of this factor.
- $a(t)$ is the time-dependent mean reversion factor
- $\sigma(t)$ is the time-dependent volatility

The zero-coupon bond price is given by:

$$P(t,T) = \exp\Big(A(t,T) - B(t,T)r(t)\Big) \tag{4.16}$$
$$A(t,T) = \ln\frac{P(0,T)}{P(0,t)} + B(t,T)f(0,t) - \frac{1}{2}B(t,T)^2V_r(0,t) \tag{4.17}$$
$$B(t,T) = E(t)\int_t^T \frac{du}{E(u)} \tag{4.18}$$

where

- $E(t)$ is given by
$$E(t) = e^{\int_0^t a(u)du}$$
- $V_r(0,t)$ is the variance of the short rate:
$$V_r(0,t) = \frac{1}{E^2(t)}\int_0^t E^2(u)\sigma^2(u)du$$
- $P(0,t)$ is the price at time 0 of a zero-coupon bond maturing at time t (observed on the market at time 0)
- $f(0,t)$ is the initial instantaneous forward rate.

Ensuring the fitting of the initial yield curve, we have the following:

$$\theta(t) = \frac{\partial}{\partial t}f(0,t) + a(t)f(0,t) + \frac{1}{2}\Big(\frac{\partial^2}{\partial t^2}V(0,t) + a(t)\frac{\partial}{\partial t}V(0,t)\Big) \tag{4.19}$$

where $V(0,t)$ given by:

$$V(0,t) = \int_0^t \sigma^2(u,t)du \tag{4.20}$$

with

$$\sigma(u,t) = \sigma(u)B(u,t). \tag{4.21}$$

Aiming on computing the capital charge, we chose to calibrate our data and simulate our exposure using the one factor Hull and White model with constant mean reversion factor and constant volatility not to introduce over-parametrization to our model.

The properties of the integral of a deterministic function relative to a Brownian motion lead to the exact discretization of the short rate model (cf. Planchet and ThÃ©rond, 2005):

$$r_{t+\delta} = r_t e^{-a\delta} + \alpha_{t+\delta} - e^{-a\delta}\alpha_t + \sigma\sqrt{\frac{1-e^{-2a\delta}}{2a}}\varepsilon_t \tag{4.22}$$

where δ is the discretization step (taken as 1 month), ε_t is a random normal standardized variable and α_t is given by:

$$\alpha(t) = f(0,t) + e^{-at}\frac{\sigma^2}{a}\int_0^t e^{au}(e^{a(t-u)}-1)du. \tag{4.23}$$

Closed forms permitting the pricing of caplets and swaptions could be derived from this model (cf. Gurrieri et al., 2009). Many calibration strategies of the HW1F (one factor Hull and White model) can be used either for the constant or time varying parameters. One method used when calibrating a model with fixed volatility and mean reversion is to fix the mean reversion parameter by the user and to find the volatility that replicates the most the prices observed on the market.

We fix the mean reversion to a rate of 3% being a common practice on the market (Bloomberg fixes the mean reversion to 3% when computing exposures and using Hull and White model) and using our HW1F we compute the prices of ATM swaptions, compare them to the prices observed on the market and fit our model by choosing the volatility that minimizes the following function g:

$$g(\sigma) = \sum_{M,T}\left[\frac{P^{Model}_{swaption}(M,T)(\sigma)}{P^{Market}_{swaption}(M,T)} - 1\right]^2 \tag{4.24}$$

M being the maturity of the swaption and T the maturity (tenor) of the underlying swap.

Using observed prices on the markets of ATM swaptions, we calibrate our model in order to get the constant σ value. Regarding the $\theta(t)$, it could be defined using the yield curve at the initial time $t = 0$.

4.5.2 Error Correction Models

The error-correction mechanism is a transformation of a general linear model incorporating past values of both an explained variable and an explanatory variables. This type of models is used in order to provide explicitly the short term deviations from long-run equilibrium in the estimated equation (cf. Hendry, 1995). Trying to understand the link between the swap rates behavior and the CDS spreads we build Error Correction Models reflecting the historical joint behavior between the explained variable (CDS spreads) and the explanatory variable (swap rates).

For each tenor m of the swap rates and the CDS spread we calibrate the following model:

$$\Delta CDS^m_t = \alpha_2\Delta Swap^m_t - \beta_1(CDS^m_{t-1} - \beta_2 Swap^m_{t-1} - \frac{\alpha_1}{\beta_1}) + \varepsilon^m_t \tag{4.25}$$

where

- ε^m_t is a random normal variable.
- CDS^m_t is the CDS spread at time t and tenor m
- $Swap^m_t$ is the swap rate at time t and tenor m
- $\Delta CDS^m_t = CDS^m_t - CDS^m_{t-1}$ having the time difference between two consecutive steps equal to one month
- $\Delta Swap^m_t = Swap^m_t - Swap^m_{t-1}$ having a one-month difference between each consecutive swap rates

Estimations are made using R software, the parameters are checked for being significant (based on the Student tests) and the residuals for being Gaussian using auto-correlation function, partial auto-correlation function, qq-plots and Kolmogorov-Smirnov tests.

The parameters estimated reflect the behavior of the variables:

- α_1 is the intercept parameter
- α_2 is the short run equilibrium
- β_1 is the speed of adjustment
- β_2 is the long run equilibrium.

After generating the $Swap_t^m$ using the Hull and White interest rate model for a monthly step up until the longest maturity we assume that the Error Correction Model calibrated on historical data could be translated into the risk neutral probability, and using Equation (4.25) we generate the simulated CDS_t^m.

Having estimated the model under the historical probability, the absence of arbitrage should be reflected in order to move to a risk free probability therefore, for each time step t we multiply the simulated CDS by a time dependent coefficient that ensures the equality between the observed CDS rates on the market at time 0 and the average of the simulated CDS across all simulations. Details can be found in the application section.

4.6 Application

The application is divided into two main parts: a first part analyzing a portfolio with a single IRS held against an investment grade sovereign and another part comparing such instrument held with three different investment grade sovereigns.

4.6.1 Portfolio description

We consider a portfolio composed of a single ATM payer interest rate swap. Semi-annual payments are in place (for the floating and the fixed leg). The swap notional is $100,000$ euros and matures after three years.

As a first step we will consider that this instrument is held with the French sovereign as a counterparty, then we will compare the differences in terms of CVA capital charge if this same portfolio is held against the French, Irish or Spanish sovereign.

4.6.2 Data used

The source of all data used is the Bloomberg terminal. The initial time chosen as $t = 0$ is the 31^{st} of December 2016.

In order to calibrate the H1WF model: initial yield curve and ATM swaption prices were used. For the ECM, historically we consider monthly observations (EOM data) ranging from end of month September 2013 up until end of month, December 2016 (39 data points) for:

- Euro swap curves at tenors: 6m, 1y, 2y and 3y,
- French sovereign (resp. Irish and Spanish) CDS mid spreads at tenors: 6m, 1y, 2y and 3y.

The yield curve at time $t = 0$ and historical observations of the swap rates and CDS spreads could be found in Appendix B.

The LGD is 60% based on Bloomberg recovery rate of 40%. All three sovereigns considered have a recovery rate of 40%.

4.6.3 Procedure

Using the current yield curve and current ATM swaption prices maturing after three years, we calibrate the Hull and White model. Minimizing the g function given in Equation (4.24), for $T = 3$ and M up to three years, the parameters results are shown in the following:

Table 4.2: Best fit parameters for the HW1F model

Model Reversion	Volatility	RMSE
3%	0.346%	0.032507

Using the short rate to generate the future bond prices and therefore swap rates, we simulate the expected exposures of the payer interest rate swap. The current CDS curve permits the deduction of the probability of defaults (as Equation (4.12) states), resulting in the calculation of the CVA as per Equation (4.11) in the independent case (no WWR).

We note that following such computation we are able to generate CVA figures that are 90% equivalent to the numbers generated from the Bloomberg terminal. Bloomberg does not account for the WWR in its computation, and the differences between our CVA figures and theirs is due to several reasons:

- Bloomberg uses ASK CDS spreads and not MID spreads. MID prices being the average of the ASK and BID CDS spreads.
- Bloomberg uses the tail options values as a proxy for the expected exposures and not the swaption values. The value of the tail option differs from the usual value of a swaption in the following: in the swaption the first coupon is prorated, whereas in the option to enter into the tail, the loss is of the entire first coupon.
- Bloomberg uses a time dependent volatility in its Hull and White Model (the mean reversion factor $a(t)$ is constant/non-time dependent and is equal to 3%).

Using the BA-CVA formula, we generate the first capital charge and computing the sensitivities of our CVA figure, we generate the capital charge amended by the FRTB method. However, WWR effect should be included in the CVA therefore, we complete our work by incorporating this latter effect.

Based on Section 4.4.2, we calibrate for each tenor an independent Error Correction Model between the CDS spreads and the swap rates at this given tenor point. Results on the coefficients of the models with the French, Irish and Spanish sovereigns can be found in Appendix C. As an example, we demonstrate the details of the ECM between the Euro swap rates and the French sovereign CDS spreads on the 3 year tenor:

Table 4.3: ECM coefficients of the French sovereign

Coefficients	Estimate	Std. Error	t value	Pr($>|t|$)
α_1	0.00077	0.000267	2.894	0.00651
α_2	0.07798	0.09121	0.855	0.3984
β_1	0.42024	0.136709	-3.074	0.00408
β_2	0.12861	0.02648	4.857	2.19E-05

We study the behavior of the model residuals: acf and pacf plots show the auto-correlation and partial auto-correlation functions that prove a low correlation in lags.

Figure 4.2: 3 year ECM ACF (France)

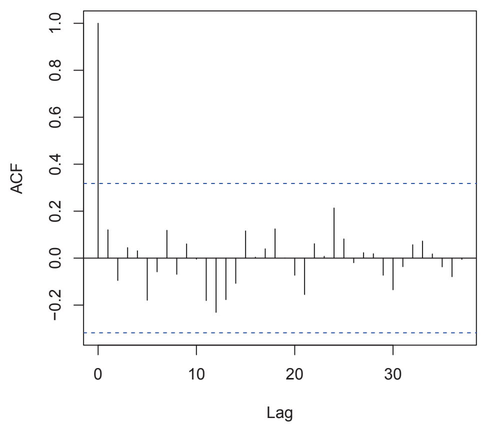
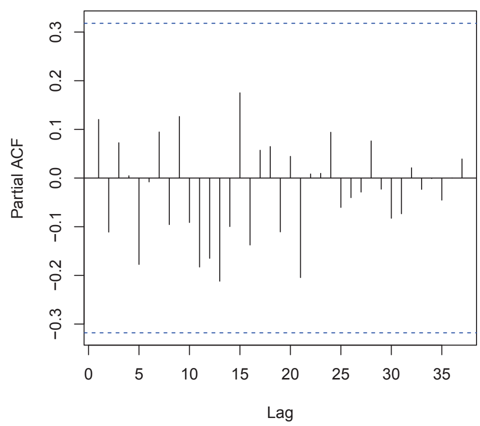
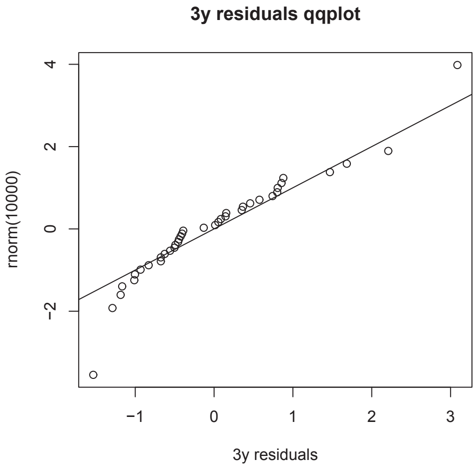


Figure 4.3: 3 year ECM PACF (France)



The QQ-plot of the residuals and results of Kolmogorov-Smirnov test ($p.value = 0.3758$) confirmed the normality of residuals.

Figure 4.4: 3 year ECM residuals QQ-plot (France)



Determining the historical relationship among these two variables, we replicate it in the future by the mean of the impulse response function: using the same coefficient and the, now simulated, swap rates we create the CDS spreads for each tenor. This would reflect the risk neutral behavior of the CDS spreads for each tenor in the future as seen at time $t = 0$.

In our computation we need to insure the verification of three conditions:

(a) The resulting simulated CDS are always positive.

(b) Having estimated the ECM under historical probability, the absence of arbitrage condition should be forced into the model therefore we need to have the average CDS spreads across all simulations, up to a given time, equal to the observed CDS spread of the term structure of credit spreads at time $t = 0$ (cf. Hull and White, 2012).

(c) Generating an increasing CDS spread structure for each future time t.

For condition (a): the model reflects the variation to the initial CDS spreads therefore it would only result in a negative CDS in the event of the generation of a very negative swap rate by the Hull and White model. This is a very rare event but is, however, an inconvenient possible outcome when using HW1F. In response to this, we neglect the scenarios (0.7 % of our scenarios) that generate such behavior knowing that in case of highly negative rates the payer interest rate swap would have a null exposure thus it will not affect our computation.

For condition (b), we need to re-calibrate the simulated CDS in order to have the expected value of the CDS spreads as observed today equal to the average CDS spreads taking all possible paths that the risk factor might follow into consideration. Based on the approach followed by Hull and White, we multiply, for each tenor j, the CDS spreads by a coefficient $\gamma(j)$ in order to respect the conditions on the equality for the CDS spreads.

For condition (c), the CDS are representative of the default probability therefore the curve at a given date of the CDS curve should be of an increasing trend. Forcing this condition into our model, at each future time t we fix the simulated CDS at a tenor j to be the maximum between the simulated CDS at this same time t, with the tenor $j-1$ and the simulated CDS at time t and tenor j.

Having responded to the three conditions, we can now use the new CDS spreads to generate the conditional probability of default and therefore compute the CVA figure while including the WWR as per Equation (4.11). The ratio between the previously computed CVA and the WWR CVA would give us the impact of this directional risk on the CVA figure and later on the capital charge amended.

4.6.4 Numerical Results

The results are generated using R software with $50,000$ simulations per portfolio. Note that for the computation of the sensitivities (in the SA-FRTB CVA method) the seed is kept constant so that variability due to the random generator is not taken into account.

Comparing Capital Charge methodologies

Starting with the French portfolio, we compute the FRTB SA-CVA and BA-CVA capital charge.

FRTB SA-CVA
Two risk factors are faced: the interest rate and the counterparty credit spread therefore sensitivities should be computed for both risk factors in order to compute their delta and vega capital requirements (vega is not applicable for the counterparty credit spreads risk factor).
We note the sensitivities as follows:

- S_{i1} the sensitivity due to a parallel shift of the risk-free yield curve of 1 bp for tenors up to one year,
- S_{i2} the sensitivity due to a parallel shift of the risk-free yield curve of 1 bp for tenors between one and five years,
- S_v the sensitivity due to an increase of all interest rate implied volatilities by 1% relative to their current values,
- S_{c1} the sensitivity due to an absolute shift of credit spreads of the counterparty by 1 bp at 0.5 years tenor,
- S_{c2} the sensitivity due to an absolute shift of credit spreads of the counterparty by 1 bp at one year tenor,
- S_{c3} the sensitivity due to an absolute shift of credit spreads of the counterparty by 1 bp at three years tenor.

Remaining risk factors that would not affect our portfolio are not represented in the remainder of this article (such as the sensitivity to a shift in the 10 years counterparty CDS curve). Additionally, inflation risk factor is not included in our work.

When neglecting the WWR impact and using the independent formula to compute the CVA, results can be summarized as per Table 4.

Table 4.4: Computed sensitivities for the portfolio held against the French sovereign

CVA no WWR	1.7268
S_{i1}	193.17
S_{i2}	519.91
S_v	3.7981
S_{c1}	-62.53
S_{c2}	-50.14
S_{c3}	918.94

The sensitivities obtained are quasi-equal to the one generated by the Bloomberg terminal: in money amount, a total of 0.07 for the interest rate parallel shifts sensitivities, 0.04 for the volatility of the rates and a 0.08 total sensitivity on the counterparty spreads.

Having one risk bucket in each risk factor, we can compute (with no inter-bucket correlations) the capital for delta and vega interest rate risk factor and the delta capital requirement for the counterparty credit spreads. In Table 4.5 we represent the results of the computation twice. A first representation is based on the 2015 consultative document and another is based on the 2016 QIS.

Table 4.5: Repartition of the capital requirements

Based on the consultative document	
K_{Delta_i}	8.507
K_{Vega_i}	5.117
K_{Delta_c}	21.238

Based on the QIS proposal	
K_{Delta_i}	9.205
K_{Vega_i}	5.117
K_{Delta_c}	4.243

We can notice that in terms of sensitivity, that the QIS reduced tremendously the capital charge for the interest rate swaps held with an investment grade sovereigns. Main differences are the change in risk weights for the counterparty credit spreads (from 2.5% to 0.5%) and the reduction of the multiplier (from 1.5 to 1) .

However, in the SA-FRTB the banks are required to account for their WWR in the computation of the CVA, therefore, we regenerate our figures using the dependency creating the WWR and this results in a multiplier factor of 1.39 to the initially computed (independent) CVA.

This figure could be compared to the α factor initially proposed in Basel II. Alpha was set to be equal to 1.4 in commercial banks and has one (of many) function to account for the WWR. Gregory (2011) explains that the purpose of an alpha correction will be to allow calculations with fixed exposures to mimic the impact of random derivatives exposures.

Few examples of the α multiplier could be seen in the following table. Note that the study of Wilde (2005) includes Wrong-Way Risk whilst the ISDA survey (2003) involved four banks making estimates based on their own portfolios and internal models.

Final results for the FRTB capital charge (Notional 100,000 euros) would be:

Table 4.7: FRTB SA-CVA capital charge

Consultative document	72.759
QIS	25.833

BA-CVA

Computing the BA-CVA would be a simple application of Equations (4.3-4.5), however a contrast between the consultative document and the QIS should be made: the risk weight for our given investment grade sovereign was reduced from 8.8% to 0.5%. The capital charge figures are:

Table 4.6: Regulatory results and published estimates of α, source: Gregory 2015

	α
Infinitely large ideal portfolio	1.0
Canabarro et al. (2003)	1.09
Wilde (2005)	1.21
ISDA (2003)	1.07-1.10
Regulatory prescribed alpha	1.4
Supervisory floor (if using own estimate)	1.2
Possible values fro concentrated portfolios	2.5 or more

Table 4.8: BA-CVA capital charge

Consultative document	551.596
QIS	29.103

SA-CVA vs BA-CVA
Having showed the impact of the documentation changes, we now focus on the QIS proposed new rules in order to compare both methodologies for one given (and further several) investment grade sovereign. Comparing both approaches we have:

Table 4.9: French portfolio capital charge

SA-CVA FRTB	25.833
BA-CVA	29.103
$\frac{BA-CVA}{SA-CVAFRTB}$	1.13

The results show that even when reducing the weights, for an interest rate swap held with the French government the Basic approach is still too conservative and amends 113% of the FRTB SA figure. However, this is not the case when dealing with counterparties with lower credit quality.

Comparing Counterparties

In order to observe the impact of the CVA capital charge methodologies on different counterparties for the same risk bucket, we consider three investment grade sovereigns that are all included in the risk bucket 1 according to Basel documentation. The sovereigns are France, Ireland and Spain.

For the three countries, we consider the same interest rate swap (in euros) therefore the impact of the exposure term in the CVA would be the same in the three cases. However, the CDS behavior of these countries are not similar: Spain has endured severe shocks recently due to the European crisis where Ireland, and mostly France, did not suffer that same effect. The CDS of all three sovereigns are attached in Appendix B.

Table 4.9 reflects the results of the preliminary computation with no WWR for Ireland and Spain.

Table 4.10: CVA sensitivity with no Wrong Way Risk

Ireland		Spain	
CVA no WWR	3.3784	CVA no WWR	4.175486
S_{i1}	391.25	S_{i1}	484.39
S_{i2}	967.47	S_{i2}	1211.4
S_v	7.3719	S_v	9.1743
S_{c1}	-62.51	S_{c1}	-62.49
S_{c2}	-50.08	S_{c2}	-50.02
S_{c3}	911.34	S_{c3}	907.6

Results show that the sensitivity to the counterparty credit spread will not change with the change of the counterparty (because we have the same exposure) however the sensitivity to the interest rate factor will increase with the decrease of the counterparty credit quality: this pattern is observed with the transition from France, to Ireland, to Spain.

In addition, when incorporating the WWR, the impact on the Irish and Spanish portfolios exceed the impact on the French portfolio with a multiplier of 1.44 for Ireland whereas the impact on the Spanish portfolio is 1.45. This is due to the historically observed volatilities and shocks in the Spanish and Irish CDS with the movements of the swap rates.

As for the Basic Approach: the exposure is the same and the risk weight is the same being in the same bucket therefore, the amended capital charge for France is equivalent to the one amended for Ireland and Spain.

Comparing both approaches will reflect that the BA-CVA is more restrictive for France whereas it is less demanding than the FRTB for the other two countries.

Table 4.11: Portfolios capital charge

	France	Ireland	Spain
SA-CVA FRTB	25.8325	45.742	55.955
BA-CVA	29.103	29.103	29.103
$\frac{\text{BA-CVA}}{\text{SA-FRTB CVA}}$	1.13	0.64	0.52

4.6.5 Proposed Scaling

Having our criticism on the amendment of the BA-CVA capital charge we propose another scaling that takes into account the credit quality of the counterparties (their CDS spreads level) in order to equalize the BA-CVA requirement to the FRTB requirement.

The motivation behind this idea is the following: if a bank has the possibility to apply the SA-FRTB, it would have the choice between applying the FRTB method or the Basic method. However, if this bank is holding an instrument with France its capital would 'benefit' if it opts for the FRTB approach whereas an instrument held with Spain would rather be computed under the BA-CVA. Knowing that the motivation in reducing the capital charge should not be the policy of a bank in order to really reflect its risk profile, however no incentives should be allowed and a better calibration of the BA-CVA should reduce such effects.

The chosen capital charge model should reflect the riskiness of the instruments held and therefore a choice based on the true translation of the real situation should be held and not a choice based on the method that reduces the most the capital required. In case a bank opts for the second choice, it would still face the damage when having to go through stress tests therefore a wise choice of method should be in place.

Trying to be more reflective of the riskiness held in the BA-CVA we propose another scaling dividing the investment grade sovereign risk bucket in a way that equalizes the SA-FRTB required capital and the BA-CVA required capital.

We highlight the fact that in this work we are neither considering marginning nor collateral however, we assume the importance of such techniques in changing the capital charge. Still, we needed to take a simple example and show the differences between the two approaches.

Having the BA-CVA risk weights linked to the SA-FRTB risk weights of the counterparty spread, when trying to recalibrate these weights we amend the change in both approaches. A proposed scaling of the risk weight that is currently at 0.5% under the QIS would be:

Table 4.12: Proposed risk weights

	Risk weight
France	0.43%
Ireland	0.86%
Spain	1.08%

Under these weights the amended BA-CVA apital charge would equal the computed FRTB SA-CVA capital charge. Comparing our scaled figures to currently proposed computation under the QIS would imply:

Table 4.13: Comparing Current to Proposed capital charges

	BA-CVA		SA-CVA FRTB	
	Current	Proposed	Current	Proposed
France	29.103	24.998	25.833	24.996
Ireland	29.103	50.1178	45.742	50.119
Spain	29.103	63.047	55.955	63.055

The changes in the risk weights would affect both approaches however, the impact would be much more important on the BA-CVA having this risk weight as a multiplier of the final equation. However, in the FRTB this weight is used to account for the risk weighted sensitivities in the delta capital requirement of the counterparty credit spreads therefore its impact would be partial.

These weights converge the BA-CVA towards the SA-FRTB which might not be ideal however it would set a limit on the use of the BA-CVA, for it not being less demanding than the FRTB method based on which part of the same risk bucket we are considering.

In Basel III, rating-based risk weights approaches for such instruments are abandoned. Instead, risk weights are defined for two buckets: investment grade and speculative grade. Such practice showed the divergence between the relative requirement between Basic and Standardized approach. Based on such, we propose to link the risk weights if not to credit ratings (because these latter could be biased), to the CDS level of the counterparty as observed earlier. A quick illustration would show a linear regression between the CDS spreads of the considered counterparties and the proposed weights for each.

4.7 Conclusion

In this work, we present the CVA topic and its implication in commercial banks in terms of capital charge. Basel newly proposed capital charge methods for the CVA are of necessity in banks where no central clearing is in place therefore we need to understand both acceptable approaches and track the differences among them starting by detailing the CVA and WWR concept.

Under the Basic approach, no modeling is required: the EAD is computed based on the Basel Standardized approach for counterparty credit risk SA-CCR and all further parameters are given by Basel papers. As for the

FRTB SA-CVA approach, we needed to compute the CVA in order to get its sensitivities resulting in the capital charge figure. CVA is the product of the exposure and the PDs : The exposures are simulated based on a chosen interest rate model (the HW1F in our case) and the default probabilities are deduced from the CDS curves. This technique resulted in the CVA figures however one important component, the Wrong Way Risk, is frequently neglected when computing CVA: we incorporated it through Error Correction Models to reflect the impact of the correlation between the exposures and the credit quality of the counterparty we are dealing with.

The application was based on portfolios containing only one instrument and held against one counterparty: an interest rate swap with an investment grade sovereign. Starting with one given counterparty, we reflected the large variances between the consultative document in 2015 and the QIS proposed in 2016 (all banks comments were highlighting the overly demanding figures of the 2015 document, resulting in the QIS proposed weights).

Considering the QIS as the regulatory current proposal for the CVA capital charge, we compared the BA-CVA figures to the one computed by means of sensitivities in the SA-FRTB. In the same counterparty risk bucket, the 'better' counterparties would be amended a basic capital more restrictive than the FRTB capital whereas, in the same bucket, for lower credit quality counterparties, the inverse is observed. Ratios as low as 50% and as high as 113% are observed between BA and SA approaches for different counterparties.

The weight amended by Basel is an average for the bucket considered however, this average is giving incentives for banks to opt for the basic approach rather than the more risk sensitive FRTB approach. Based on this, we proposed a re-scaling of the weights in order to boost the basic approach and make it more reflective of the risk facing this given counterparty. The proposed scaled weights depend on the CDS spread of the counterparty ranging from 0.4% up to 1.1% instead of the current average 0.5%.

We acknowledge the fact that these conclusions are applicable for one counterparty in the sovereign investment grade bucket and could reflect other deductions in other counterparties buckets case. Plus, in our study we neglected the fact that margin or collateral could be in place and this could change the conclusions drawn from the figures. This being said, the work intension is to reflect the CVA capital charge methodologies and impact on commercial banks where no CVA hedging is in place, nor central clearing. Therefore, these portfolios were chosen to be reflective of the possible situation small banks are facing.

While waiting for a finalized version of the CVA capital charge from the regulator, this article highlighted the proposed methodologies, compared them between counterparties and suggested a re-scaling of the weights, based on a WWR incorporated model, in opposition with the practice of letting go of the credit rating (or CDS levels) and just focusing on the grade because such techniques will lack granularity and thus will not reflect the actual risk faced on the market because in one grade counterparties might have very differing characteristics, correlations and responses to market behavior.

Appendices

Appendix 4.1: FRTB tables

All tables in this appendix are summarizing the details given in the QIS on CVA by Basel (cf. BCBS, 2016 (b))

Table 4.14: Buckets Distribution

Risk types	**Bucket division**
Interest rates	Individual currencies
Foreign Exchange	Individual currencies except the bank's domestic currency
Counterparty Credit Spread	Divided following credit quality and sector (refer to Table 17 in this appendix)
Reference Credit Spread	Divided between sector and credit quality (refer to Table 18 in this appendix).
Equity	Divided following the size, region and sector (refer to Table 19 in this appendix).
Commodity	Divided into commodity groups (refer to Table 20 in this appendix).

Table 4.15: Risk weights based on the bucketing of the risk factors

<table>
<tr><th>Risk factor</th><th>Component</th><th colspan="3">Risk weights</th></tr>
<tr><td rowspan="6">Interest rates</td><td rowspan="5">Delta Risk</td><td rowspan="4">USD, EUR, GBP, AUD CAD, SEK and JPY</td><td>0-1 years</td><td>1.70%</td></tr>
<tr><td>1-5 years</td><td>1.27%</td></tr>
<tr><td>> 5 years</td><td>1.06%</td></tr>
<tr><td>Inflation</td><td>1.59%</td></tr>
<tr><td>Other currencies</td><td>Yield curve and inflation</td><td>2.25%</td></tr>
<tr><td>Vega Risk</td><td colspan="2">Interest rate and inflation</td><td>135%</td></tr>
<tr><td rowspan="2">Foreign Exchange</td><td>Delta Risk</td><td colspan="2">Foreign-domestic</td><td>21%</td></tr>
<tr><td>Vega Risk</td><td colspan="2">FX volatilities</td><td>110%</td></tr>
<tr><td rowspan="15">Counterparty Credit Spread</td><td rowspan="15">Delta Risk</td><td rowspan="7">Inv. Grade</td><td>Bucket 1</td><td>0.50%</td></tr>
<tr><td>Bucket 2</td><td>1.00%</td></tr>
<tr><td>Bucket 3</td><td>5.00%</td></tr>
<tr><td>Bucket 4</td><td>3.00%</td></tr>
<tr><td>Bucket 5</td><td>3.00%</td></tr>
<tr><td>Bucket 6</td><td>2.00%</td></tr>
<tr><td>Bucket 7</td><td>1.50%</td></tr>
<tr><td rowspan="8">HY/NR</td><td>Bucket 8</td><td>3.00%</td></tr>
<tr><td>Bucket 9</td><td>4.00%</td></tr>
<tr><td>Bucket 10</td><td>12.00%</td></tr>
<tr><td>Bucket 11</td><td>7.00%</td></tr>
<tr><td>Bucket 12</td><td>8.50%</td></tr>
<tr><td>Bucket 13</td><td>5.50%</td></tr>
<tr><td>Bucket 14</td><td>5.00%</td></tr>
<tr><td>Bucket 15</td><td>12.00%</td></tr>
</table>

Risk factor	Component	Risk weights		
Reference Credit Spread	Delta Risk	Inv. Grade	Bucket 1	0.50%
			Bucket 2	1.00%
			Bucket 3	5.00%
			Bucket 4	3.00%
			Bucket 5	3.00%
			Bucket 6	2.00%
			Bucket 7	1.50%
		HY/NR	Bucket 8	3.00%
			Bucket 9	4.00%
			Bucket 10	12.00%
			Bucket 11	7.00%
			Bucket 12	8.50%
			Bucket 13	5.50%
			Bucket 14	5.00%
			Bucket 15	12.00%
	Vega Risk		Volatilities	191%
Equity	Delta Risk		Bucket 1	55%
			Bucket 2	60%
			Bucket 3	45%
			Bucket 4	55%
			Bucket 5	30%
			Bucket 6	35%
			Bucket 7	40%
			Bucket 8	50%
			Bucket 9	70%
			Bucket 10	50%
			Bucket 11	70%
Equity	Vega Risk	Volatilities	Large capitalisation	78%
			Small capitalisation	135%
Commodity	Delta Risk		Bucket 1	30%
			Bucket 2	35%
			Bucket 3	60%
			Bucket 4	80%
			Bucket 5	40%
			Bucket 6	45%
			Bucket 7	20%
			Bucket 8	35%
			Bucket 9	25%
			Bucket 10	35%
			Bucket 11	50%
	Vega Risk		Volatilities	191%

Table 4.16: Correlations In-buckets

<table>
<tr><th>Risk factor</th><th>Comp.</th><th colspan="6">Correlation</th></tr>
<tr><td rowspan="7">Interest rates</td><td rowspan="6">Delta Risk</td><td rowspan="5">USD, EUR, GBP, AUD, CAD, SEK, JPY</td><td></td><td>0-1 y</td><td>1-5 y</td><td>$>$ 5 y</td><td>Inflation</td></tr>
<tr><td>0-1 y</td><td>100%</td><td>70%</td><td>30%</td><td>40%</td></tr>
<tr><td>1-5 y</td><td></td><td>100%</td><td>70%</td><td>40%</td></tr>
<tr><td>$>$ 5 y</td><td></td><td></td><td>100%</td><td>40%</td></tr>
<tr><td>Infl.</td><td></td><td></td><td></td><td>100%</td></tr>
<tr><td>Other currencies</td><td colspan="5">40%</td></tr>
<tr><td>Vega Risk</td><td>Interest rate volatilities and inflation</td><td colspan="5">40%</td></tr>
<tr><td rowspan="3">Counterparty Credit Spread</td><td rowspan="3">Delta Risk</td><td colspan="4">Different tenors same counterparty</td><td colspan="2">60%</td></tr>
<tr><td colspan="4">Same tenors different counterparties</td><td colspan="2">35%</td></tr>
<tr><td colspan="4">Different tenors different counterparties</td><td colspan="2">23%</td></tr>
</table>

Table 4.17: Cross-Bucket Correlation

Risk factor	**Cross-bucket correlation**														
Interest rates	50%														
Foreign Exchange	50%														
Counterparty Credit Spread															
%	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	100	75	10	20	25	20	15	50	37	5	10	13	10	12	0
2		100	5	15	20	15	10	37	50	2.5	7.5	10	7.5	5	0
3			100	5	15	20	5	5	2.5	50	2.5	7.5	10	2.5	0
4				100	20	25	5	10	7.5	2.5	50	10	12	2.5	0
5					100	25	5	12	10	7.5	10	50	12	2.5	0
6						100	5	10	7.5	10	12	12	50	2.5	0
7							100	7	5	2.5	2.5	2.5	2.5	50	0
8								100	75	10	20	25	20	15	0
9									100	5	15	20	15	10	0
10										100	5	15	20	5	0
11											100	20	25	5	0
12												100	25	5	0
13													100	5	0
14														100	0
15															100

Reference Credit Spread															
%	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	100	75	10	20	25	20	15	50	37	5	10	13	10	12	0
2		100	5	15	20	15	10	37	50	2.5	7.5	10	7.5	5	0
3			100	5	15	20	5	5	2.5	50	2.5	7.5	10	2.5	0
4				100	20	25	5	10	7.5	2.5	50	10	12	2.5	0
5					100	25	5	12	10	7.5	10	50	12	2.5	0
6						100	5	10	7.5	10	12	12	50	2.5	0
7							100	7	5	2.5	2.5	2.5	2.5	50	0
8								100	75	10	20	25	20	15	0
9									100	5	15	20	15	10	0
10										100	5	15	20	5	0
11											100	20	25	5	0
12												100	25	5	0
13													100	5	0
14														100	0
15															100

Equity	Buckets between 1-10	15%
	All buckets pairs that include 11	0%
Commodity	Buckets between 1-10	20%
	All buckets pairs that include 11	0%

Table 4.18: Buckets for counterparty credit spread delta risk

no	Credit quality	Sector
1	Investment grade	Sovereigns including central banks, multilateral development banks
2		Local government, government-backed non-financials, education and public administration
3		Financials including government-backed financials
4		Basic materials, energy, industrials, agriculture, manufacturing, mining and quarrying
5		Consumer goods and services, transportation and storage, administrative and support service activities
6		Technology, telecommunications
7		Health care, utilities, professional and technical activities
8	High yield (HY) & non-rated (NR)	Sovereigns including central banks, multilateral development banks
9		Local government, government-backed non-financials, education and public administration
10		Financials including government-backed financials
11		Basic materials, energy, industrials, agriculture, manufacturing, mining and quarrying
12		Consumer goods and services, transportation and storage, administrative and support service activities
13		Technology, telecommunications
14		Health care, utilities, professional and technical activities
15	Not applicable	Other sector

Table 4.19: Buckets for reference credit spread's delta and vega risks

no	**Credit quality**	**Sector**
1	Investment grade (IG)	Sovereigns including central banks, multilateral development banks
2		Local government, government-backed non-financials, education and public administration
3		Financials including government-backed financials
4		Basic materials, energy, industrials, agriculture, manufacturing, mining and quarrying
5		Consumer goods and services, transportation and storage, administrative and support service activities
6		Technology, telecommunications
7		Health care, utilities, professional and technical activities
8	High yield (HY) & non-rated (NR)	Sovereigns including central banks, multilateral development banks
9		Local government, government-backed non-financials, education and public administration
10		Financials including government-backed financials
11		Basic materials, energy, industrials, agriculture, manufacturing, mining and quarrying
12		Consumer goods and services, transportation and storage, administrative and support service activities
13		Technology, telecommunications
14		Health care, utilities, professional and technical activities
15	Not applicable	Other sector

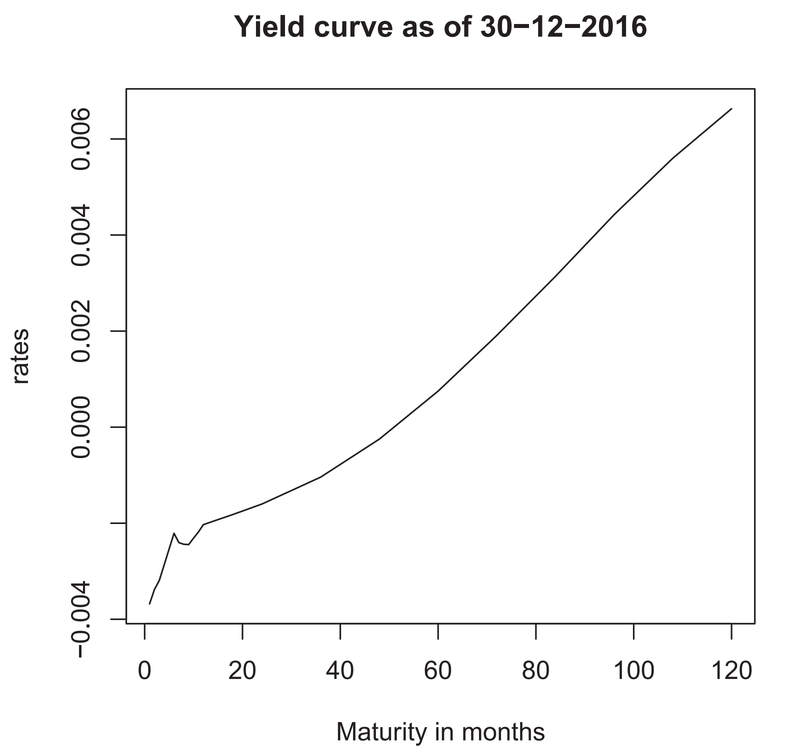
Table 4.20: Buckets for equity's delta and vega risks

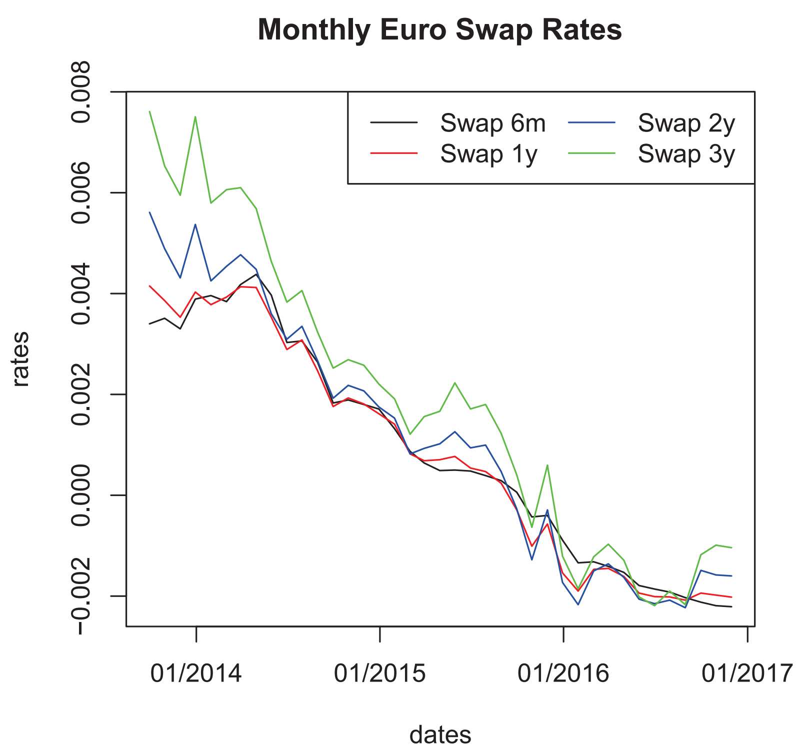
no	**Size**	**Region**	**Sector**
1	Large	Emerging market economies	Consumer goods and services, transportation and storage, administrative and support service activities, healthcare, utilities
2			Telecommunications, industrials
3			Basic materials, energy, agriculture, manufacturing, mining and quarrying
4			Financials including government-backed financials, real estate activities, technology
5		Advanced economies	Consumer goods and services, transportation and storage, administrative and support service activities, healthcare, utilities
6			Telecommunications, industrials
7			Basic materials, energy, agriculture, manufacturing, mining and quarrying
8			Financials including government-backed financials, real estate activities, technology
9	Small	Emerging market economies	All sectors described under bucket 1, 2, 3 and 4.
10		Advanced economies	All sectors described under bucket 5, 6, 7 and 8.
11	Not applicable		Other sector

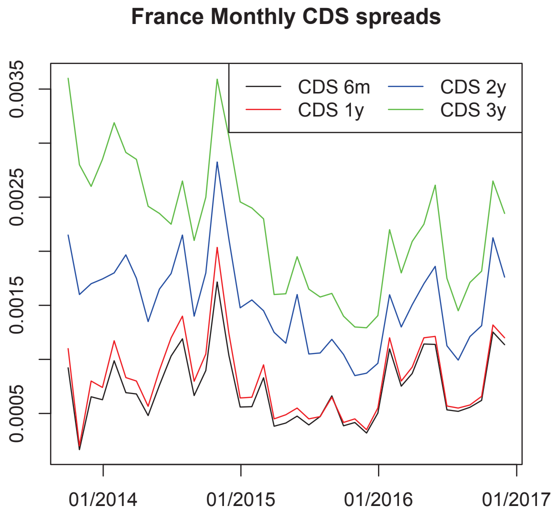
Table 4.21: Buckets for commodity's delta and vega risks

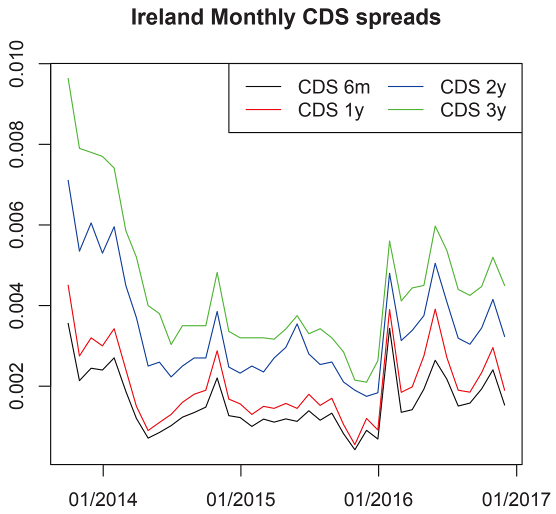
no	Commodity group	Examples
1	Energy - Solid combustibles	coal, charcoal, wood pellets, nuclear fuel (such as uranium)
2	Energy - Liquid combustibles	crude oil (such as Light-sweet, heavy, WTI and Brent); biofuels (such as bioethanol and biodiesel); petrochemicals (such as propane, ethane, gasoline, methanol and butane); refined fuels (such as jet fuel, kerosene, gasoil, fuel oil, naptha, heating oil and diesel)
3	Energy - Electricity and carbon trading	electricity (such as spot, day-ahead, peak and off-peak); carbon emissions trading (such as certified emissions reductions, in-delivery month EUA, RGGI CO2 allowance and renewable energy certificates)
4	Freight	dry-bulk route (such as capesize, panamex, handysize and supramax); liquid-bulk/gas shipping route (such as suezmax, aframax and very large crude carriers)
5	Metals - non-precious	base metal (such as aluminium, copper, lead, nickel, tin and zinc); steel raw materials (such as steel billet, steel wire, steel coil, steel scrap and steel rebar, iron ore, tungsten, vanadium, titanium and tantalum); minor metals (such as cobalt, manganese, molybdenum)
6	Gaseous combustibles	natural gas; liquefied natural gas
7	Precious metals (including gold)	gold; silver; platinum; palladium
8	Grains & oilseed	corn; wheat; soybean (such as soybean seed, soybean oil and soybean meal); oats; palm oil; canola; barley; rapeseed (such as rapeseed seed, rapeseed oil, and rapeseed meal); red bean, sorghum; coconut oil; olive oil; peanut oil; sunflower oil; rice
9	Livestock & dairy	cattle (such live and feeder); hog; poultry; lamb; fish; shrimp; dairy (such as milk, whey, eggs, butter and cheese)
10	Softs and other agriculturals	cocoa; coffee (such as arabica and robusta); tea; citrus and orange juice; potatoes; sugar; cotton; wool; lumber and pulp; rubber
11	Other commodity	industrial minerals (such as potash, fertiliser and phosphate rocks), rare earths; terephthalic acid; flat glass

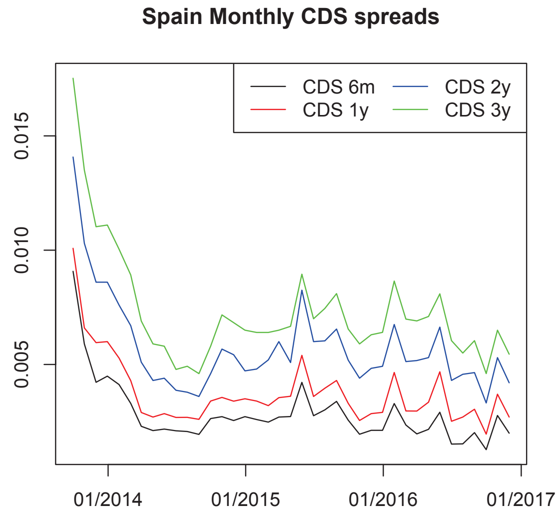
Appendix 4.2: Data Illustration






France Monthly CDS spreads
CDS 6m
CDS 1y
CDS 2y
CDS 3y
0.0005
0.0015
0.0025
0.0035
01/2014
01/2015
01/2016
01/2017


Ireland Monthly CDS spreads
CDS 6m
CDS 1y
CDS 2y
CDS 3y
0.002
0.004
0.006
0.008
0.010
01/2014
01/2015
01/2016
01/2017



Appendix 4.3: Error Correction Models Details

Table 4.22: ECM coefficients of the French sovereign

FRANCE	coefficients	Estimate	Std. Error	t value	Pr(> $\|t\|$)
1y	α_1	0.00048	0.000148	3.274	0.002389
	α_2	-0.0169	0.17373	-0.097	0.92302
	β_1	0.60524	0.160513	-3.771	0.000603
	β_2	0.01384	0.02684	0.515	0.609
2y	α_1	0.00077	0.000219	3.544	0.00114
	α_2	0.12161	0.10532	1.155	0.25606
	β_1	0.56855	0.154585	-3.678	0.000784
	β_2	0.07351	0.02481	2.962	0.00531
3y	α_1	0.00077	0.000267	2.894	0.00651
	α_2	0.07798	0.09121	0.855	0.3984
	β_1	0.42024	0.136709	-3.074	0.00408
	β_2	0.12861	0.02648	4.857	2.19E-05

Table 4.23: ECM coefficients of the Irish sovereign

IRELAND	coefficients	Estimate	Std. Error	t value	Pr(> |t|)
1y	α_1	0.00108	0.000333	3.236	0.00265
	α_2	0.08909	0.38147	0.234	0.81671
	β_1	0.55865	0.140229	-3.984	0.000327
	β_2	0.01755	0.06631	0.265	0.793
2y	α_1	0.00092	0.000396	2.334	0.02549
	α_2	-0.07	0.25145	-0.278	0.78243
	β_1	0.33519	0.115137	-2.911	0.00622
	β_2	0.1738	0.078253	2.221	0.0326
3y	α_1	0.00076	0.000381	1.988	0.0547
	α_2	0.0637	0.19253	0.331	0.7427
	β_1	0.22995	0.090585	-2.539	0.0157
	β_2	0.27134	0.083492	3.25	0.00246

Table 4.24: ECM coefficients of the Spanish sovereign

SPAIN	coefficients	Estimate	Std. Error	t value	Pr(> |t|)
1y	α_1	0.00165	0.000393	4.199	0.000175
	α_2	0.14955	0.40404	0.37	0.71351
	β_1	0.51674	0.100137	-5.16	9.88E-06
	β_2	0.28042	0.09838	2.85	0.0071
2y	α_1	0.00206	0.000531	3.875	0.000448
	α_2	0.25401	0.31079	0.817	0.41927
	β_1	0.43285	0.094748	-4.568	5.86E-05
	β_2	0.37128	0.117568	3.158	0.00316
3y	α_1	0.00203	0.00056	3.633	0.000889
	α_2	0.32759	0.24558	1.334	0.19083
	β_1	0.35556	0.082397	-4.315	0.000124
	β_2	0.4496	0.116709	3.852	0.000449

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Conclusion

The main purpose of my thesis is to provide Bank Audi Risk Management with the most recent tools to cope with the regulatory modifications noticeably in terms of trading book risk management and counterparty credit risk. We worked on understanding Basel III new approaches and requirements and building our own tools in order to internally assess the risk specific to Bank Audi and the market conditions in which it operates.

Respectively, the subjects handled in this thesis are the following:

- Introducing the methods used under the new FRTB regulations and showing how they compare to the traditional Value at Risk methodologies for the general interest rate risk factor in the banks' trading book,
- Understanding the counterparty credit risk specificity especially after recent financial crisis and detailing the approach used by Basel III. Computing its capital charge under different hedging scenarios while comparing it with an internal approach that incorporates the historical observations and the future forecasting the bank would see fit to be introduced in its computation.
- Having different entities with heavy derivatives portfolio and no central clearing in place, the third part was intended to observe the impact of the CVA capital charge on banks under different regulatory approaches. An addition was to propose a method that incorporates the WWR in the CVA computation while reducing the simulation burden to a minimum.

We initiate the work with an introductory chapter that explains Bank Audi's operating environment and details the key changes in the region for the year 2016, highlights the banks balance sheet and instruments repartition notably the derivatives instruments. A wider angle view on the derivatives market is shared as well based on BIS figures. In addition, a full descriptive review of the transition between having no international regulatory governance in the banking sector to starting with Basel IV reforms is presented in the same chapter.

The content of this first chapter is intended to give the key components of the thesis: aiming to apply this work in Bank Audi an overview of its financials is a must, focusing in a second part on the counterparty credit risk, CVA and WWR a knowledge of the derivatives market (internationally and locally) is necessary as well. All the work being based on the understanding of Basel III rules, we needed to have a look on the history of these regulations to get the incentives that led to each new amendment.

The second chapter discusses the new market risk requirement for the trading book. The FRTB framework is a longly awaited addition to the market risk. The impact of this new proposal will result in several changes due to the important modifications it proposes in terms of computing the capital charge and placing the instruments between trading or banking book. The focus of our work in this article was to comprehend the SBA methodology and the components of its formulas. After having done so, compare it to the traditional VaR methodology (applied in the bank) in order to see the convergence or divergence among these approaches based on the portfolio we are dealing with. The FRTB handles under his sensitivity based approach different risk factors such as general interest rate risk, fx risk, commodities, credit spreads and equity risk. In Bank Audi the main risk factor in the trading book in the interest rate risk therefore we focused on that component in the application part of the article.

The application was embarked based on portfolios of zero coupon bonds held with one or many counterparties and only general interest rate risk was considered in this work. The chosen governments were France, Germany, US and Turkey. The choice of these portfolios resulted from our need to see the impact in different environments: stable European markets, US differing conditions and emergent markets such as the Turkish market. Bank Audi has a large exposure to these countries especially the Turkish market therefore this choice was judged as adequate. Moreover, the results showed indeed the variation between the outcome for each portfolio or even for the mixed portfolios.

The third chapter discusses a different type of risk which is the counterparty credit risk. After the 2007-2009 sub-prime financial crisis, a worldwide interest converged towards the derivatives and their impact. Higher importance was granted to the adequate risk assessment of these exposures and a new methodology was implemented by Basel (the SA-CCR). In Bank Audi several entities deal with derivatives, therefore a particular look on the new approaches is necessary to the bank. In the paper, we described the SA-CCR and tried to explain its components and the incentives for Basel to propose such techniques. Afterwards, we suggested an econometrical model based on Vasicek interest rate model that permits to estimate future exposures of the derivatives based on historically observed behavior of the risk factors and projected estimated forecast of these same factors.

Calibrating our models on periods of stress, we used a 'modified' version of the historically calibrated Vasicek model, under risk neutral probability, in order to reflect the forecast estimation of the FOMC for the upcoming years. Applications were based on three derivative instruments types: interest rate swaps, FX forwards and FX plain vanilla options, being the most traded instruments. The results showed that the model calibrated internally is representative of the standardized approach at almost 80% when no hedging is in place.

Completing the work, we considered portfolios with different netting or margining scenarios in order to reflect the impact of such hedging techniques on the capital charge figures under both standardized and internal model. Results showed how the hedging is beneficial under both approaches however, a higher reduction in the capital charge is observed under the SA-CCR framework highlighting Basel's III incentives for the banks to hedge their portfolios.

The fourth chapter is intended to clarify the CVA concept. For banks that have not fully incorporated clearing houses or did not fully hedge their CVA, a capital charge is newly amended by the international regulator. The paper develops the two accepted methods to compute the CVA capital charge: the Basic approach and the FRTB standardized approach. We used hypothetical un-margined portfolios with one given counterparty to build a comparison between the two techniques capital amendments. Criticizing the fact that Basel let go of the credit rating ranks and instead uses only investment or non investment grade in order to divide the counterparties, we suggested a scaling of the proposed weights in order to incorporate the specific credit quality.

Another main addition of this article is the incorporation of the WWR through ECM models. The WWR is often neglected when computing the CVA figure which is not reflective of the real situation. Typically, this risk is added by changing the exposures in order to incorporate the correlation with the time of default. However, our approach worked in an inverse structure: keep the simulated exposures and compute the probability of default based on the given exposures along several simulations.

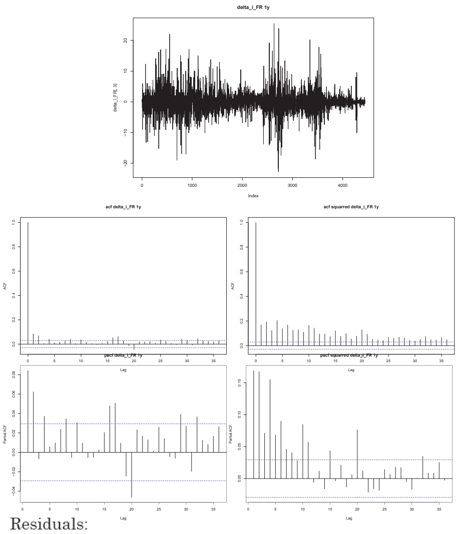
This thesis was encouraged by Bank Audi in the purpose of incorporating these new Basel rules in the bank's capital charge computation methodologies and to have alternative approaches for internal assessments. The contribution to the bank is brought by the three Basel methodologies explained in each paper and the alternative models suggested in order to compute the capital charge. Not focusing on the conditions of highly developed markets, we tried to illustrate through hypothetical applications the case of the Lebanese market. Proposed forthcoming studies could be: to englobe in the internal model against the FRTB framework several risk factors, for the counterparty credit risk a study on more complex derivatives could be held, as for the CVA in order to encourage the bank to hedge their CVA further research on the impact of different hedging strategies could be interesting for the bank. Another proposed study would be in discussing the bilateral CVA for Bank Audi and not only the Basel amended unilateral figure.

Supplementary Material for Chapter 2

Models details: GARCH

French portfolio

1 year



```
Residuals:
    Min      1Q  Median      3Q     Max
-6.0704 -0.5202  0.0000  0.4649  9.7850

Coefficient(s):
    Estimate  Std. Error  t value Pr(>|t|)
a0  3.61004    0.08049    44.85   <2e-16 ***
a1  0.25932    0.01661    15.61   <2e-16 ***
a2  0.16088    0.01293    12.44   <2e-16 ***
a3  0.20312    0.01472    13.80   <2e-16 ***
a4  0.25465    0.01443    17.65   <2e-16 ***

Diagnostic Tests:
Jarque Bera Test
data:  Residuals
X-squared = 7938.133, df = 2, p-value < 2.2e-16

Box-Ljung test
data:  (reg3_FR$res)
X-squared = 32.4358, df = 6, p-value = 1.346e-05

data:  (reg3_FR$res)
X-squared = 75.7836, df = 16, p-value = 9.483e-10
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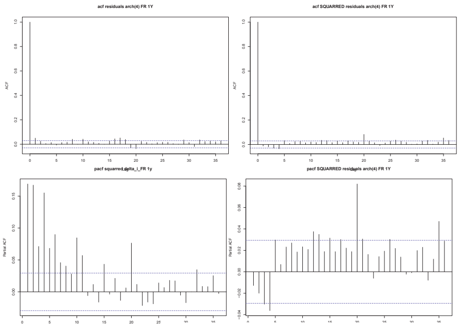
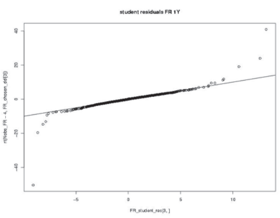
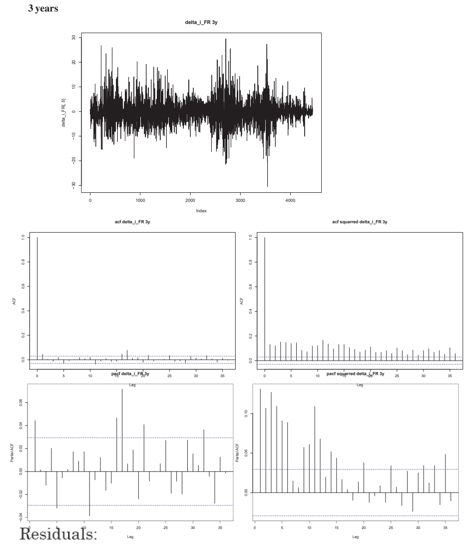
Residuals:





3 years



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Residuals:
     Min       1Q   Median      3Q      Max
-5.36557 -0.56104 -0.02333  0.49438  5.97047

Coefficient(s):
    Estimate  Std. Error  t value Pr(>|t|)
a0  8.81915    0.24526    35.96   <2e-16 ***
a1  0.17105    0.01412    12.11   <2e-16 ***
a2  0.14844    0.01258    11.80   <2e-16 ***
a3  0.15220    0.01197    12.71   <2e-16 ***
a4  0.17154    0.01587    10.81   <2e-16 ***

Diagnostic Tests:
Jarque Bera Test
data:  Residuals
X-squared = 1896.455, df = 2, p-value < 2.2e-16

Box-Ljung test
data:  (reg5_FR$res)
X-squared = 15.642, df = 6, p-value = 0.01581

data:  (reg5_FR$res)
X-squared = 48.4296, df = 16, p-value = 4.065e-05
```
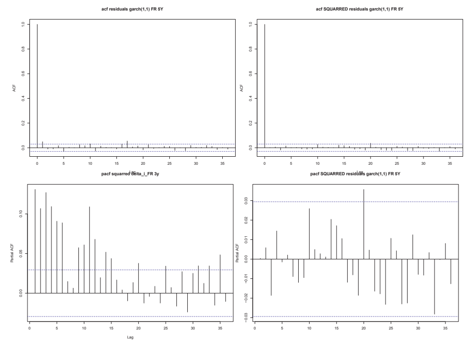
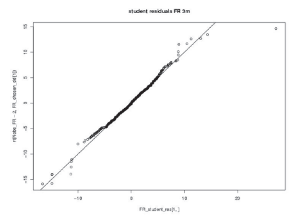
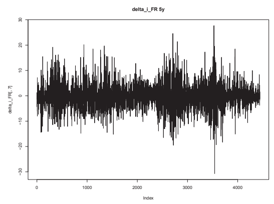

Residuals:

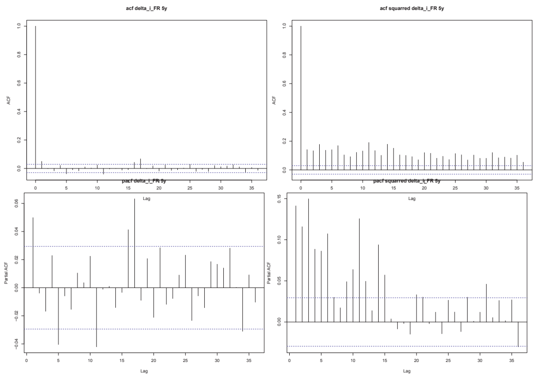




French portfolio

5 years





Residuals:
Min 1Q Median 3Q Max
-4.73312 -0.61938 -0.02239 0.54222 4.72180

Coefficient(s):

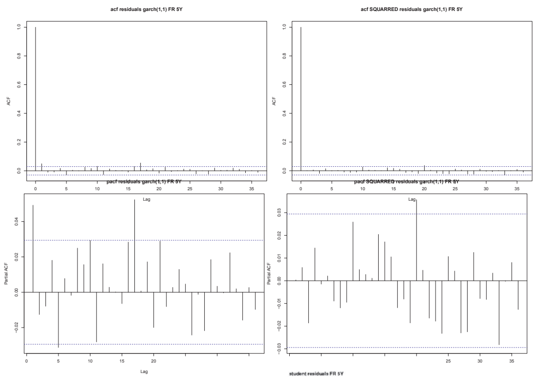
	Estimate	Std. Error	t value	Pr(>|t|)	
a0	0.166302	0.030192	5.508	3.63e-08	***
a1	0.054412	0.004290	12.684	< 2e-16	***
b1	0.938945	0.004611	203.625	< 2e-16	***

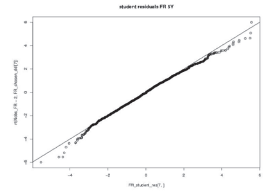
Diagnostic Tests:
Jarque Bera Test
data: Residuals
X-squared = 362.6718, df = 2, p-value < 2.2e-16

Box-Ljung test
data: (reg7_FR$res)
X-squared = 25.3896, df = 9, p-value = 0.002569

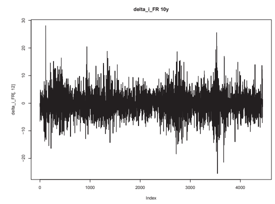
data: (reg7_FR$res)
X-squared = 49.6951, df = 19, p-value = 0.0001453

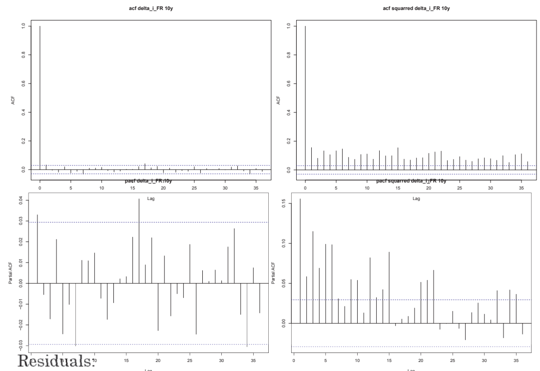
Residuals:





10 years





Residuals:
Min 1Q Median 3Q Max
-5.09905 -0.61744 -0.02173 0.54443 7.74929

Coefficient(s):

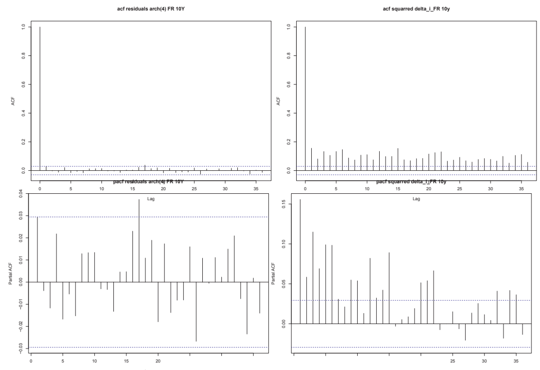
	Estimate	Std. Error	t value	Pr(>|t|)	
a0	12.21561	0.33315	36.667	< 2e-16	***
a1	0.11511	0.01405	8.193	2.22e-16	***
a2	0.05964	0.01278	4.666	3.07e-06	***
a3	0.08035	0.01532	5.245	1.56e-07	***
a4	0.11303	0.01522	7.429	1.10e-13	***

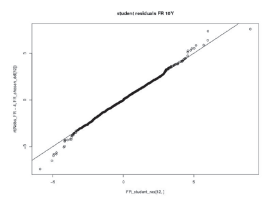
Diagnostic Tests:
Jarque Bera Test
data: Residuals
X-squared = 817.3323, df = 2, p-value < 2.2e-16

Box-Ljung test
data: (reg12_FR$res)
X-squared = 11.3044, df = 6, p-value = 0.07941

data: (reg12_FR$res)
X-squared = 24.8475, df = 16, p-value = 0.07256

Residuals:

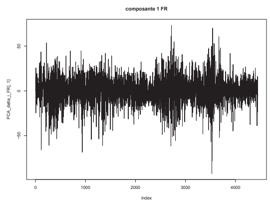


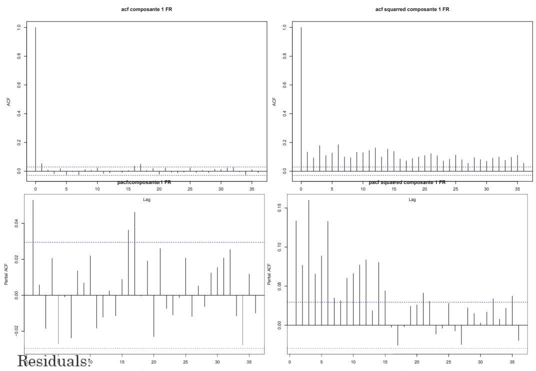


Models details: PCA

French portfolio

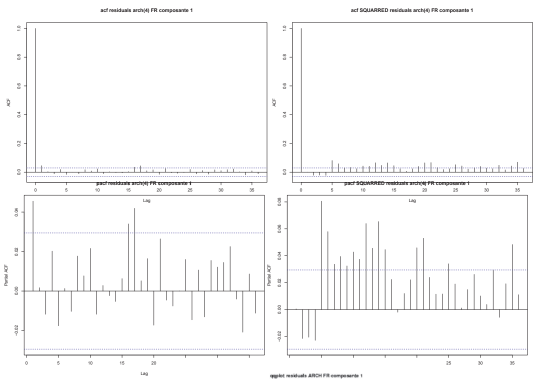
1stcomponent

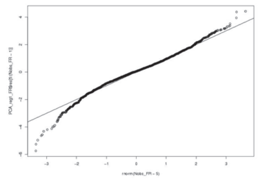




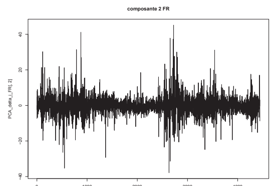

```
Residuals:
     Min       1Q   Median       3Q      Max
-5.73837 -0.53274  0.03952  0.62434  4.42131

Coefficient(s):
    Estimate  Std. Error  t value Pr(>|t|)
a0 121.57244     3.54520   34.292  < 2e-16 ***
a1   0.11596     0.01345    8.620  < 2e-16 ***
a2   0.08494     0.01239    6.854 7.17e-12 ***
a3   0.09123     0.01531    5.960 2.53e-09 ***
a4   0.12309     0.01628    7.559 4.06e-14 ***

Diagnostic Tests:
Jarque Bera Test
data:  Residuals
X-squared = 639.6134, df = 2, p-value < 2.2e-16

Box-Ljung test
data:  (PCA_reg1_FR$res)
X-squared = 17.1664, df = 6, p-value = 0.008691

data:  (PCA_reg1_FR$res)
X-squared = 34.937, df = 16, p-value = 0.004054
```

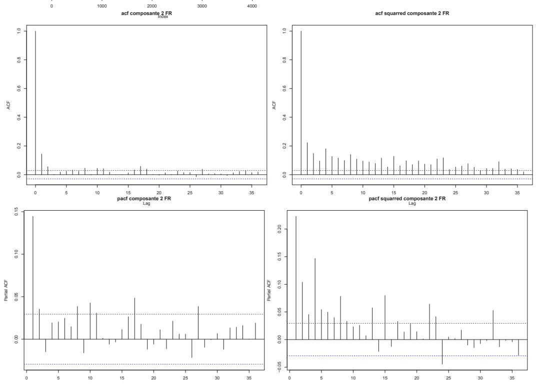
Residuals:





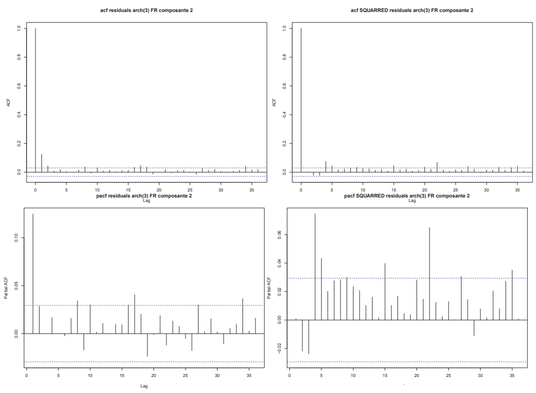
2ndcomponent

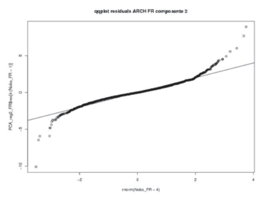





```
Residuals:
     Min       1Q   Median       3Q      Max
-8.81017 -0.56238 -0.02336  0.55761  9.00150

Coefficient(s):
    Estimate  Std. Error  t value Pr(>|t|)
a0  0.239108    0.032708    7.31 2.66e-13 ***
a1  0.093837    0.003646   25.74  < 2e-16 ***
b1  0.905422    0.002708  334.38  < 2e-16 ***

Diagnostic Tests:
Jarque Bera Test
data:  Residuals
X-squared = 5005.76, df = 2, p-value < 2.2e-16

Box-Ljung test
data:  (PCA_reg2_FR$res)
X-squared = 124.7142, df = 9, p-value < 2.2e-16

data:  (PCA_reg2_FR$res)
X-squared = 149.2132, df = 19, p-value < 2.2e-16
```

Residuals:

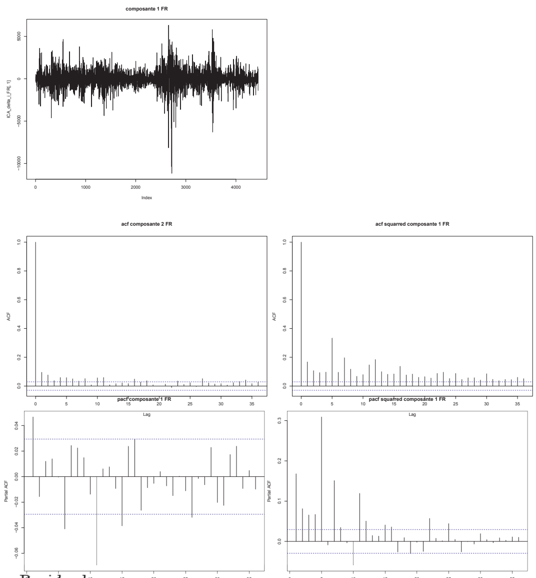




Models details: ICA

French portfolio

1stcomponent



Residuals:
    Min   1Q   Median   3Q   Max
-11.29122 -0.45046   0.01099   0.48296   4.67054

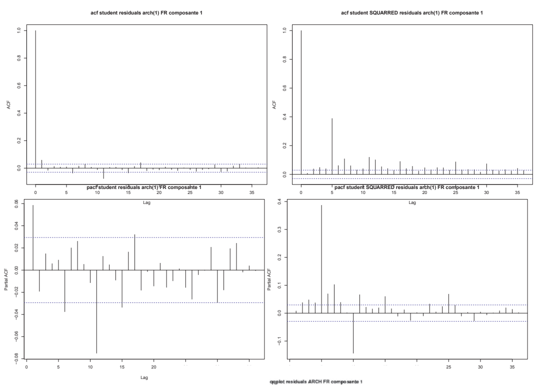
Coefficient(s):
    Estimate Std. Error t value Pr(>|t|)
a0 9.736e+05   1.035e+04   94.04   <2e-16 ***
a1 1.975e-01   1.408e-02   14.03   <2e-16 ***

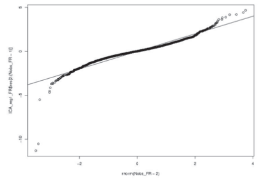
Diagnostic Tests:
Jarque Bera Test
data: Residuals
X-squared = 23898.63, df = 2, p-value < 2.2e-16

Box-Ljung test
data: (ICA_reg1_FR$res)
X-squared = 24.5896, df = 9, p-value = 0.00346

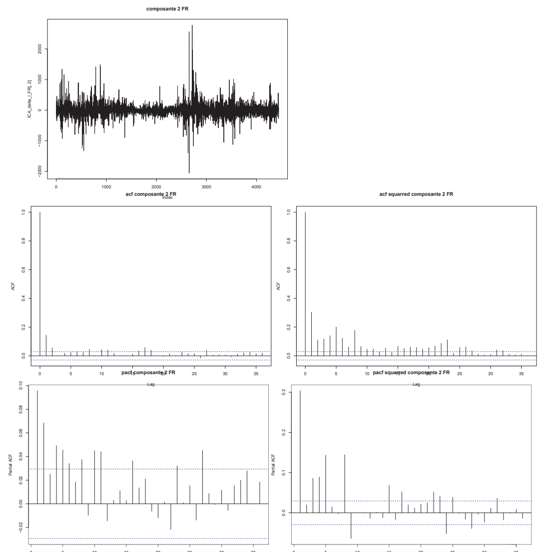
data: (ICA_reg1_FR$res)
X-squared = 33.6574, df = 19, p-value = 0.02016

Residuals:





2ndcomponent



Residuals:
    Min   1Q   Median   3Q   Max
-7.60514 -0.50569 -0.02706 0.49418 9.21689

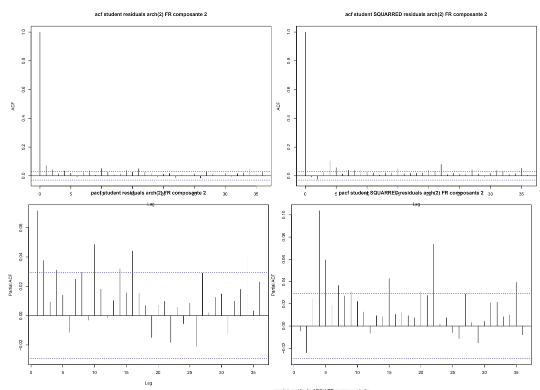
Coefficient(s):
    Estimate Std. Error t value Pr(>|t|)
a0 2.421e+04   3.658e+02   66.18   <2e-16 ***
a1 3.370e-01   1.510e-02   22.32   <2e-16 ***
a2 2.438e-01   1.671e-02   14.59   <2e-16 ***

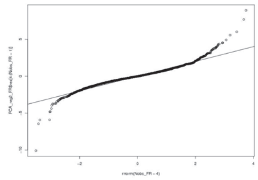
Diagnostic Tests:
Jarque Bera Test
data: Residuals
X-squared = 10919.72, df = 2, p-value < 2.2e-16

Box-Ljung test
data: (ICA_reg2_FR$res)
X-squared = 25.0392, df = 8, p-value = 0.001531

data: (ICA_reg2_FR$res)
X-squared = 58.7792, df = 18, p-value = 3.218e-06

Residuals:

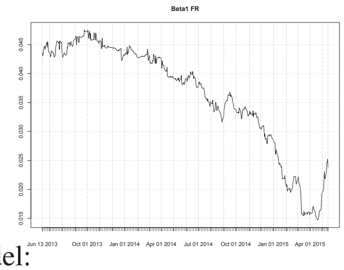




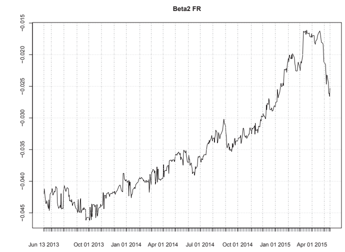
Models details: DNS

French portfolio

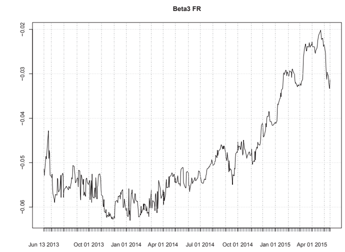
Beta1



Beta2



Beta3

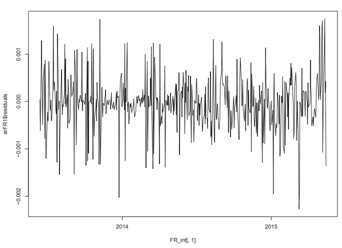


Model:

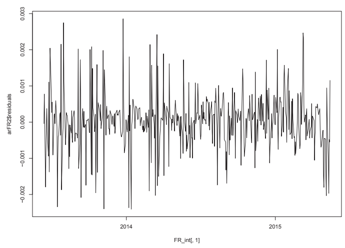
beta	Summary
1 Arima(2,1,0)	Coefficients: ar1 ar2 -0.0630 0.0275 s.e. 0.0449 0.0452 sigma^2 estimated as 3.318e-07: log likelihood=3020.2 AIC=-6034.39 AICc=-6034.34 BIC=-6021.75
2 Arima (2,1,0)	Coefficients: ar1 ar2 -0.2600 -0.0544 s.e. 0.0447 0.0450 sigma^2 estimated as 5.876e-07: log likelihood=2877.32 AIC=-5748.64 AICc=-5748.59 BIC=-5736
3 Arima (0,1,1)	Coefficients: ma1 -0.3035 s.e. 0.0414 sigma^2 estimated as 2.278e-06: log likelihood=2538.58 AIC=-5073.15 AICc=-5073.13 BIC=-5064.72

Residuals:

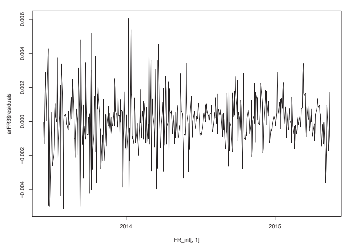
Beta1



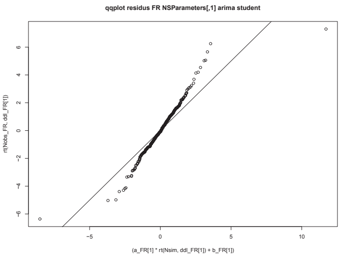
Beta2



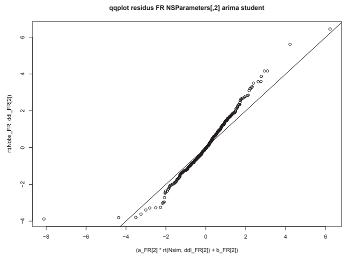
Beta3



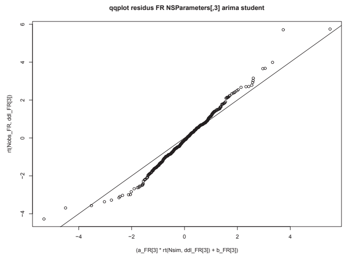
Beta1



Beta2



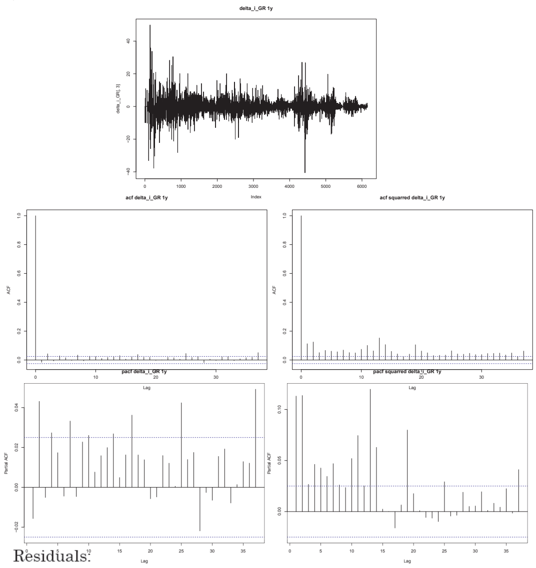
Beta3



Models details: GARCH

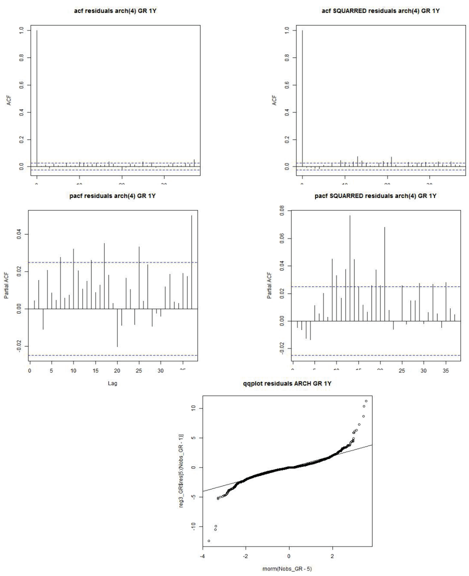
German portfolio

1 year

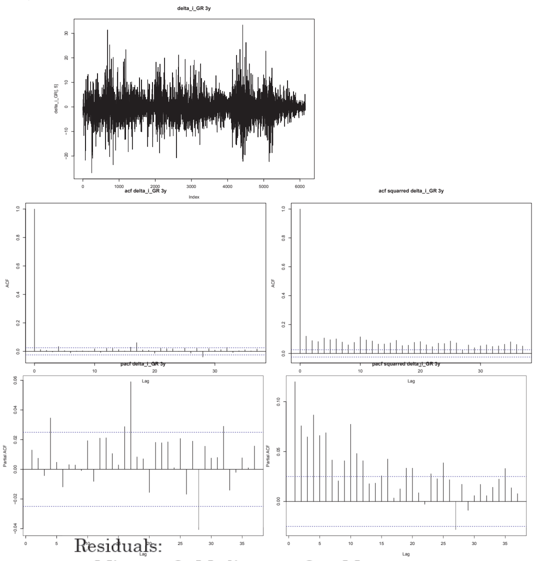


```
Residuals:
    Min      1Q  Median      3Q     Max 
-12.4201 -0.4833  0.0000  0.3885 11.2368 

Coefficient(s):
    Estimate  Std. Error  t value Pr(>|t|)    
a0  7.145446    0.063346   112.80   <2e-16 ***
a1  0.211985    0.009627    22.02   <2e-16 ***
a2  0.215897    0.006652    32.45   <2e-16 ***
a3  0.117835    0.007375    15.98   <2e-16 ***
a4  0.131845    0.008740    15.09   <2e-16 ***

Diagnostic Tests:
Jarque Bera Test
data:  Residuals
X-squared = 67949.11, df = 2, p-value < 2.2e-16

Box-Ljung test
data:  (reg3_GR$res)
X-squared = 17.2582, df = 6, p-value = 0.00838

data:  (reg3_GR$res)
X-squared = 43.0141, df = 16, p-value = 0.0002781
```

Residuals:

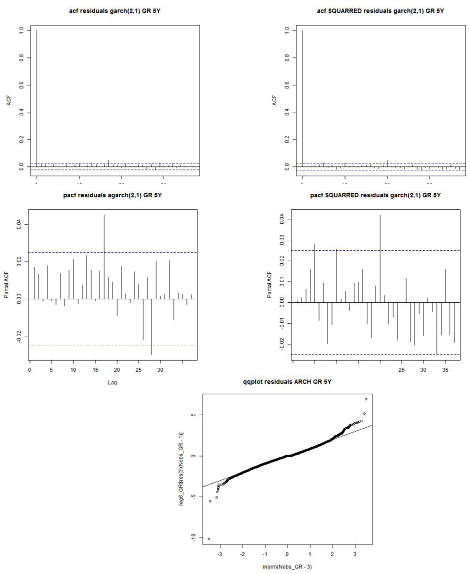


5 years



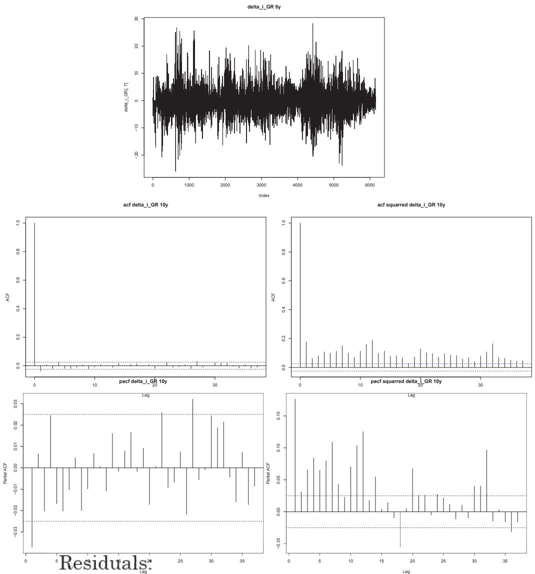
```
Residuals:
    Min      1Q  Median      3Q     Max 
-7.7320 -0.5499  0.0000  0.4786  7.2407 

Coefficient(s):
    Estimate  Std. Error  t value Pr(>|t|)    
a0  12.06447     0.20344   59.301   <2e-16 ***
a1   0.13472     0.01195   11.272   <2e-16 ***
a2   0.10563     0.01018   10.375   <2e-16 ***
a3   0.08330     0.01000    8.329   <2e-16 ***
a4   0.13552     0.01083   12.513   <2e-16 ***

Diagnostic Tests:
Jarque Bera Test
data:  Residuals
X-squared = 4416.911, df = 2, p-value < 2.2e-16

Box-Ljung test
data:  (reg5_GR$res)
X-squared = 9.868, df = 6, p-value = 0.1303

data:  (reg5_GR$res)
X-squared = 38.8967, df = 16, p-value = 0.001126
```

Residuals:



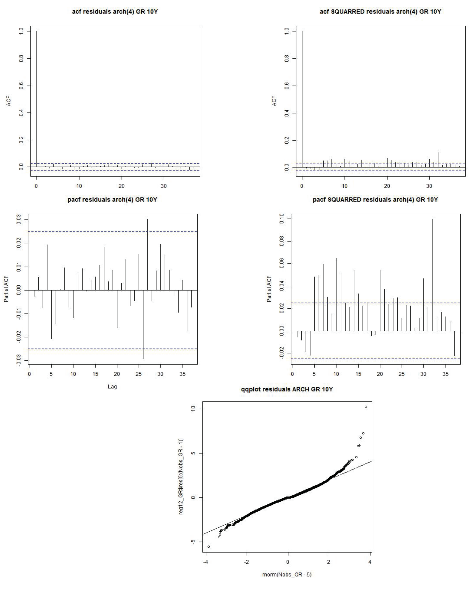
German portfolio

10 years

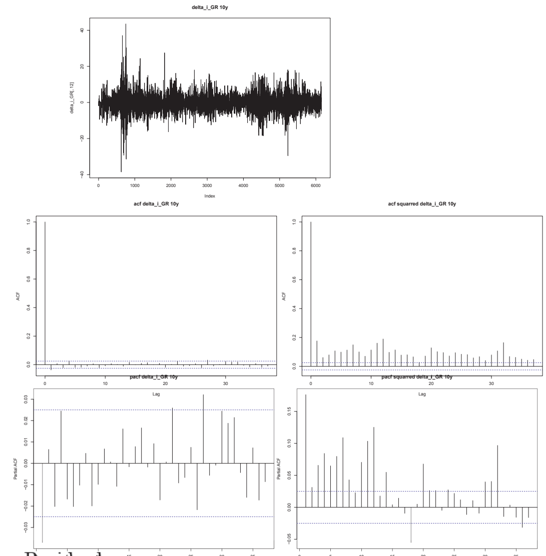


```
Residuals:
    Min      1Q  Median      3Q     Max
-6.3680 -0.6138  0.0000  0.5303  6.3607

Coefficient(s):
    Estimate  Std. Error  t value Pr(>|t|)
a0  0.178953    0.033524    5.338  9.4e-08 ***
a1  0.058930    0.007703    7.651  2.0e-14 ***
b1  0.617810    0.169525    3.644 0.000268 ***
b2  0.316580    0.161867    1.956 0.050489 .

Diagnostic Tests:
Jarque Bera Test
data:  Residuals
X-squared = 1170.889, df = 2, p-value < 2.2e-16

Box-Ljung test
data:  (reg7_GR$res)
X-squared = 10.5802, df = 9, p-value = 0.3056

data:  (reg7_GR$res)
X-squared = 33.5836, df = 19, p-value = 0.02057
```

Residuals:

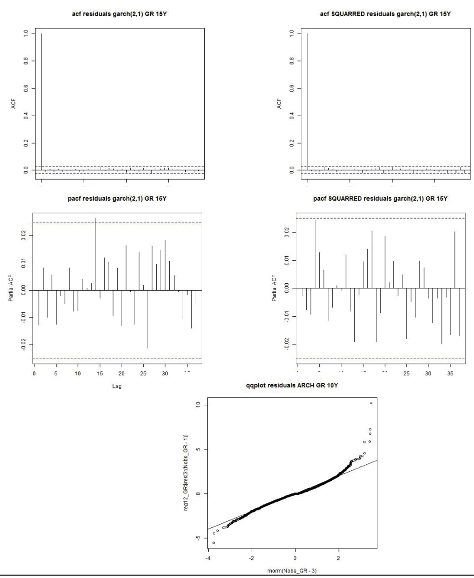


15 years



```
Residuals:
    Min      1Q  Median      3Q     Max
-5.5602 -0.6058  0.0000  0.5160 10.2042

Coefficient(s):
    Estimate  Std. Error  t value Pr(>|t|)
a0 12.579786    0.207858   60.521  < 2e-16 ***
a1  0.138887    0.012851   10.808  < 2e-16 ***
a2  0.045180    0.008757    5.159 2.48e-07 ***
a3  0.120161    0.009578   12.546  < 2e-16 ***
a4  0.130194    0.010304   12.635  < 2e-16 ***

Diagnostic Tests:
Jarque Bera Test
data:  Residuals
X-squared = 4486.163, df = 2, p-value < 2.2e-16

Box-Ljung test
data:  (reg12_GR$res)
X-squared = 8.6379, df = 6, p-value = 0.195

data:  (reg12_GR$res)
X-squared = 14.6967, df = 16, p-value = 0.547
```

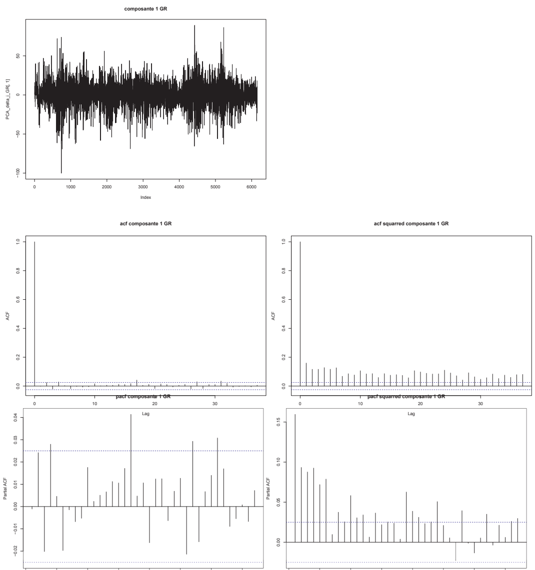
Residuals:



Models details: PCA

German portfolio

1stcomponent



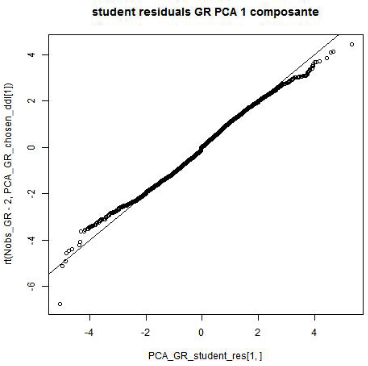
Residuals:
```
    Min       1Q  Median      3Q     Max
-4.56792 -0.53426  0.02244  0.63714  4.88677

Coefficient(s):
    Estimate  Std. Error  t value Pr(>|t|)
a0  2.056734    0.299706    6.863 6.77e-12 ***
a1  0.046242    0.002897   15.964  < 2e-16 ***
b1  0.944432    0.003650  258.774  < 2e-16 ***
```

Diagnostic Tests:
Jarque Bera Test
data: Residuals
X-squared = 586.1751, df = 2, p-value < 2.2e-16

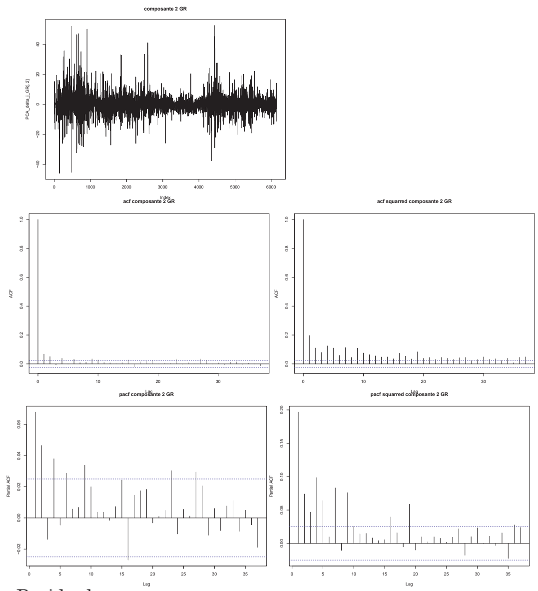
Box-Ljung test
data: (PCA_reg1_GR$res)
X-squared = 13.3144, df = 9, p-value = 0.1489

data: (PCA_reg1_GR$res)
X-squared = 30.2757, df = 19, p-value = 0.04839

Residuals:



2ndcomponent



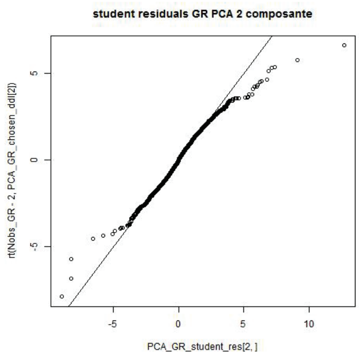
Residuals:
```
    Min      1Q  Median      3Q     Max
-7.7833 -0.5362  0.0000  0.5080 11.0117

Coefficient(s):
    Estimate  Std. Error  t value Pr(>|t|)
a0  0.217065    0.020560    10.56   <2e-16 ***
a1  0.065766    0.002069    31.79   <2e-16 ***
b1  0.932958    0.001783   523.28   <2e-16 ***
```

Diagnostic Tests:
Jarque Bera Test
data: Residuals
X-squared = 13685.65, df = 2, p-value < 2.2e-16

Box-Ljung test
data: (PCA_reg2_GR$res)
X-squared = 96.2088, df = 9, p-value < 2.2e-16

data: (PCA_reg2_GR$res)
X-squared = 114.6503, df = 19, p-value = 1.11e-15

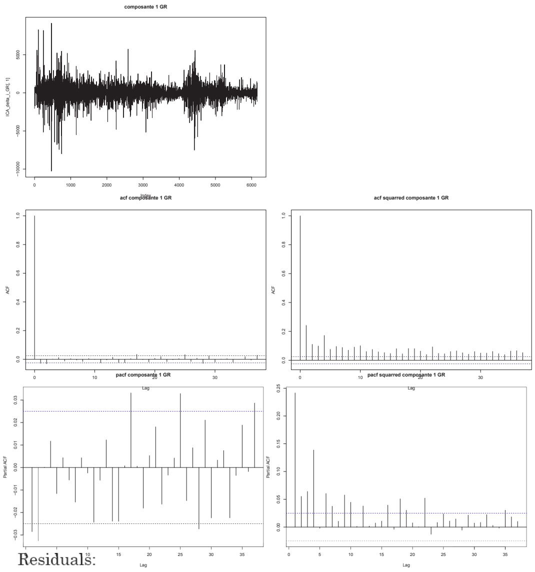
Residuals:



Models details: ICA

German portfolio

1stcomponent



Residuals:
Min 1Q Median 3Q Max
-9.884134 -0.434891 0.006042 0.500854 5.768775

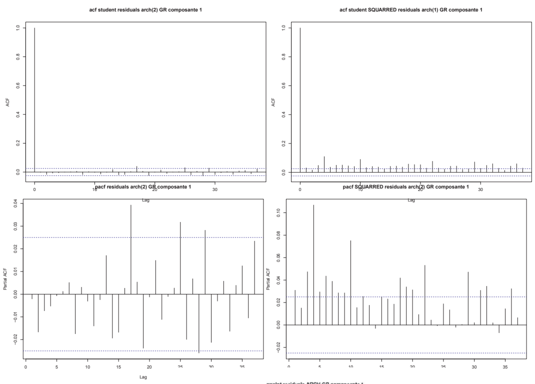
Coefficient(s):
Estimate Std. Error t value Pr(>|t|)
a0 2.619e+05 3.626e+03 72.24 <2e-16 ***
a1 1.393e-01 9.894e-03 14.08 <2e-16 ***
a2 8.100e-02 8.035e-03 10.08 <2e-16 ***

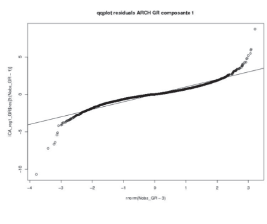
Diagnostic Tests:
Jarque Bera Test
data: Residuals
X-squared = 9212.247, df = 2, p-value < 2.2e-16

Box-Ljung test
ata: (ICA_reg1_GR$res)
X-squared = 4.3735, df = 8, p-value = 0.822

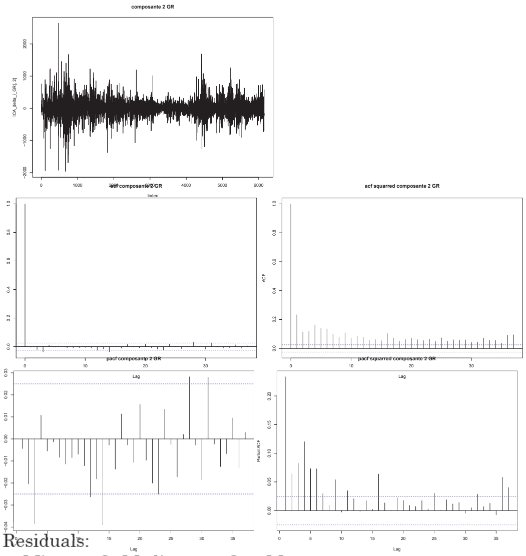
data: (ICA_reg1_GR$res)
X-squared = 25.2611, df = 18, p-value = 0.1179

Residuals:





2ndcomponent



Residuals:
Min 1Q Median 3Q Max
-8.2013 -0.4336 0.0000 0.4045 9.7705

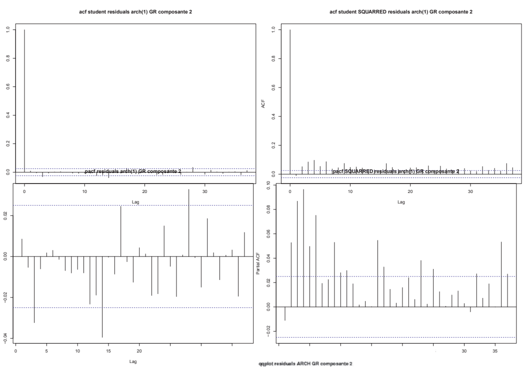
Coefficient(s):
Estimate Std. Error t value Pr(>|t|)
a0 7.616e+05 8.521e+03 89.38 <2e-16 ***
a1 2.223e-01 1.269e-02 17.52 <2e-16 ***

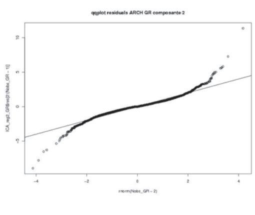
Diagnostic Tests:
Jarque Bera Test
data: Residuals
X-squared = 18336, df = 2, p-value < 2.2e-16

Box-Ljung test
data: (ICA_reg2_GR$res)
X-squared = 8.4976, df = 9, p-value = 0.4849

data: (ICA_reg2_GR$res)
X-squared = 48.9126, df = 19, p-value = 0.07448

Residuals:

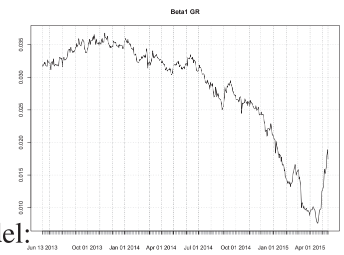


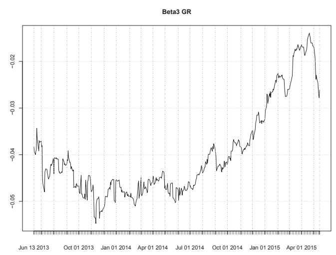


Models details: DNS

German portfolio

Beta1 **Beta2** **Beta3**



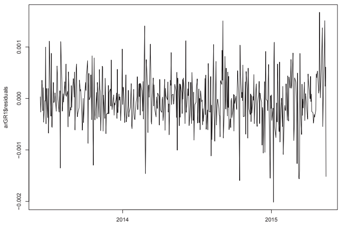


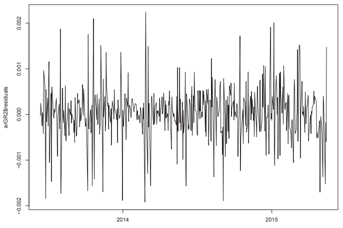
Model:

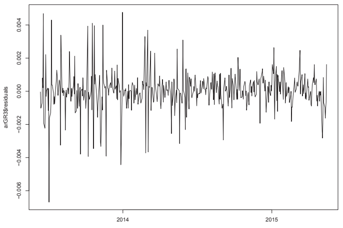
beta	Summary
1 Arima (1,1,1) (1,1,3)	Coefficients: ar1 ma1 -0.4954 0.6440 s.e. 0.1498 0.1308 sigma^2 estimated as 2.444e-07: log likelihood=3096.58 AIC=-6187.16 AICc=-6187.11 BIC=-6174.51
2 Arima (1,1,1) (1,1,3)	Coefficients: ar1 ma1 -0.7301 0.8313 s.e. 0.0908 0.0721 sigma^2 estimated as 3.525e-07: log likelihood=3005.09 AIC=-6004.17 AICc=-6004.12 BIC=-5991.53
3 Arima (0,1,1) (2,1,2)	Coefficients: ma1 -0.0241 s.e. 0.0478 sigma^2 estimated as 1.303e-06: log likelihood=2678.18 AIC=-5352.37 AICc=-5352.34 BIC=-5343.94

Residuals:

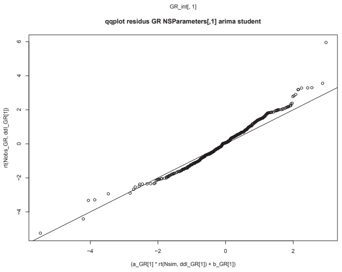
Beta1 **Beta2** **Beta3**

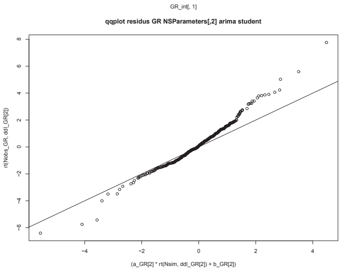


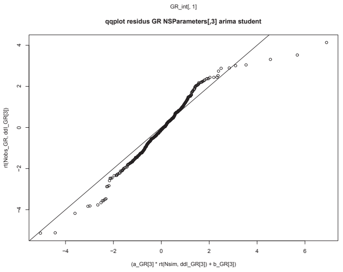




Beta1 **Beta2** **Beta3**



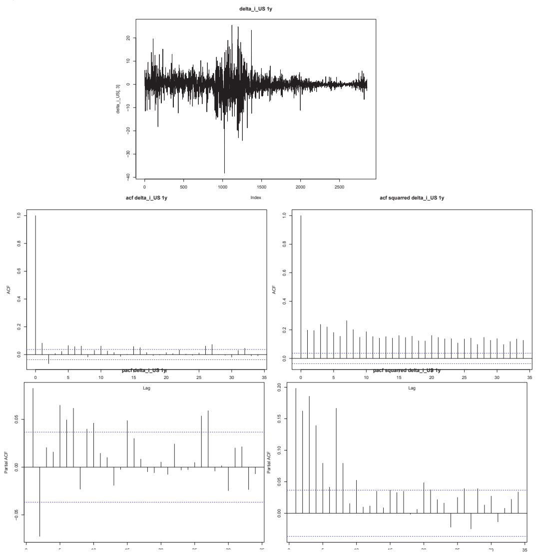




Models details: GARCH

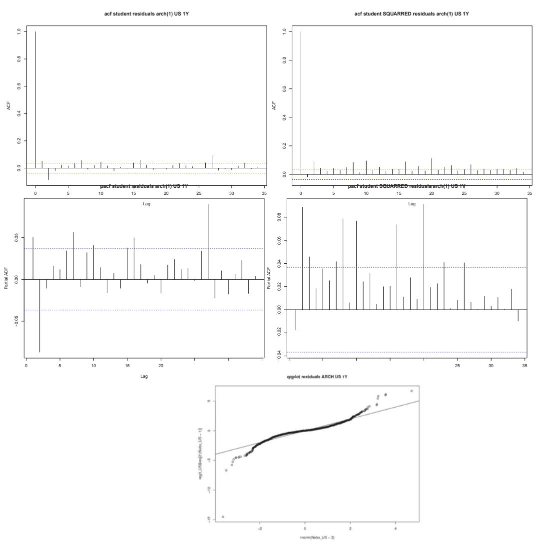
US portfolio

1 year

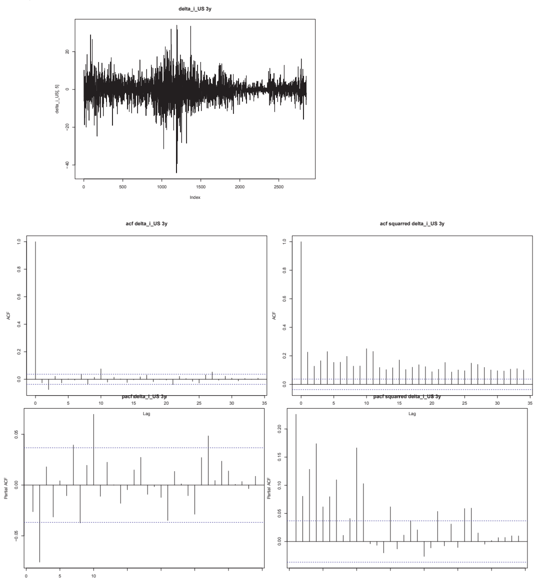


```
Residuals:
     Min        1Q    Median        3Q       Max
-14.525000 -0.355763  0.007204  0.388481  6.733236

Coefficient(s):
   Estimate  Std. Error  t value Pr(>|t|)
a0  6.91663    0.05938   116.48   <2e-16 ***
a1  0.79097    0.03034    26.07   <2e-16 ***

Diagnostic Tests:
Jarque Bera Test
data:  Residuals
X-squared = 55793.71, df = 2, p-value < 2.2e-16


Box-Ljung test
data:  (reg3_US$res)
X-squared = 49.7564, df = 9, p-value = 1.197e-07

data:  (reg3_US$res)
X-squared = 68.1181, df = 19, p-value = 1.885e-07
```

Residuals:

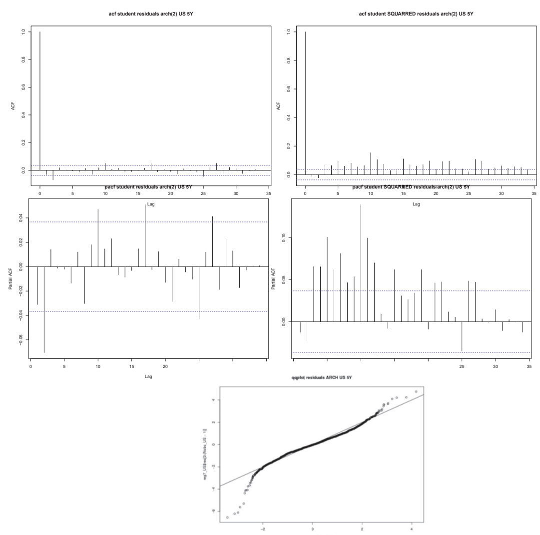


5 years



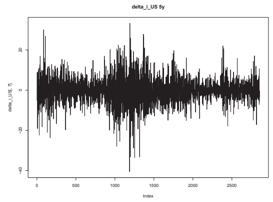
```
Residuals:
     Min        1Q    Median        3Q       Max
-10.431422 -0.461839 -0.002923  0.476231  6.630552

Coefficient(s):
   Estimate  Std. Error  t value Pr(>|t|)
a0 11.18218    0.25270    44.25   <2e-16 ***
a1  0.45083    0.01928    23.38   <2e-16 ***
a2  0.32189    0.02142    15.03   <2e-16 ***

Diagnostic Tests:
Jarque Bera Test
data:  Residuals
X-squared = 13037.79, df = 2, p-value < 2.2e-16

Box-Ljung test
data:  (reg5_US$res)
X-squared = 29.5942, df = 6, p-value = 4.694e-05

data:  (reg5_US$res)
X-squared = 40.9778, df = 16, p-value = 0.0005595
```

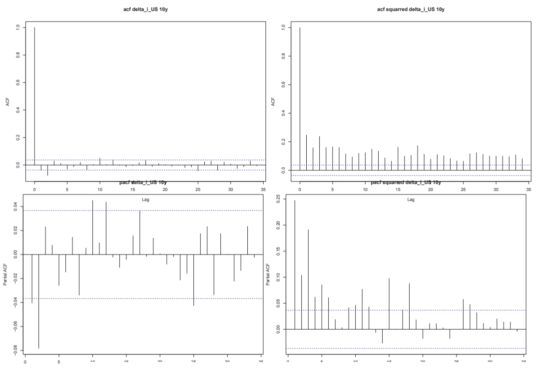
Residuals:



US portfolio

10 years





Residuals:

Min	1Q	Median	3Q	Max
-7.22947	-0.57397	-0.02127	0.57580	4.72168

Coefficient(s):

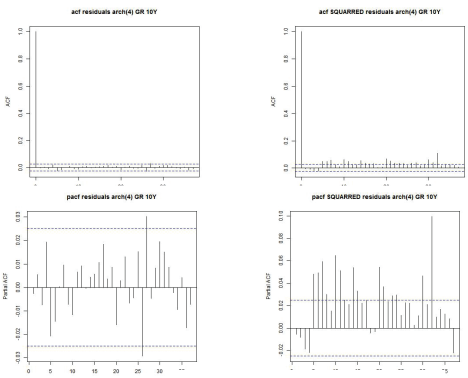
	Estimate	Std. Error	t value	Pr(>|t|)	
a0	19.83569	0.83687	23.702	< 2e-16	***
a1	0.11874	0.01965	6.041	1.53e-09	***
a2	0.11606	0.01971	5.888	3.90e-09	***
a3	0.19706	0.01900	10.371	< 2e-16	***
a4	0.10884	0.02071	5.257	1.47e-07	***

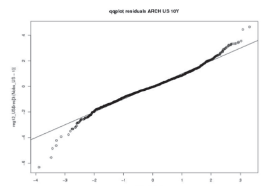
Diagnostic Tests:
Jarque Bera Test
data: Residuals
X-squared = 1173.917, df = 2, p-value < 2.2e-16

Box-Ljung test
data: (reg7_US$res)
X-squared = 31.4174, df = 6, p-value = 2.11e-05

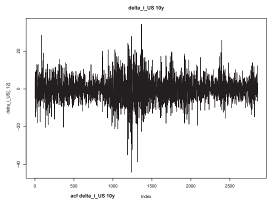
data: (reg7_US$res)
X-squared = 40.3052, df = 16, p-value = 0.0007026

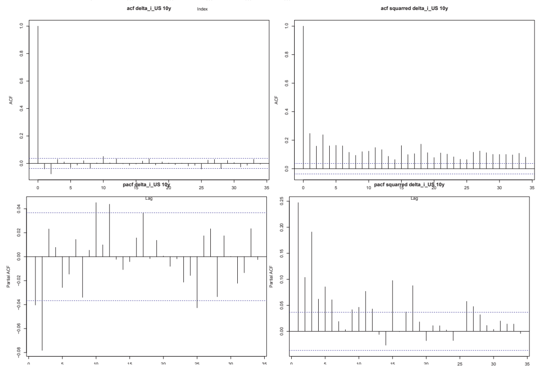
Residuals:





15 years





Residuals:

Min	1Q	Median	3Q	Max
-5.80296	-0.62588	-0.03771	0.60602	5.09507

Coefficient(s):

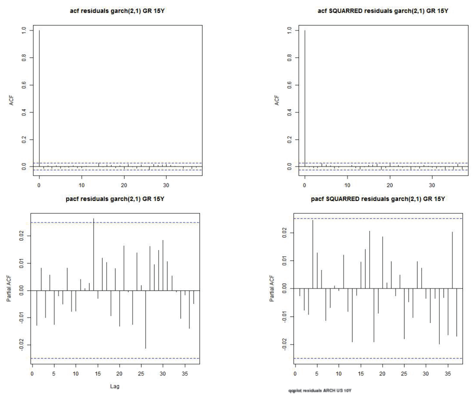
	Estimate	Std. Error	t value	Pr(>|t|)	
a0	21.91557	0.92264	23.753	< 2e-16	***
a1	0.13005	0.01798	7.232	4.76e-13	***
a2	0.07848	0.02165	3.625	0.000289	***
a3	0.18200	0.01968	9.250	< 2e-16	***
a4	0.08577	0.02111	4.062	4.87e-05	***

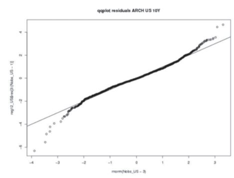
Diagnostic Tests:
Jarque Bera Test
data: Residuals
X-squared = 369.9421, df = 2, p-value < 2.2e-16

Box-Ljung test
data: (reg12_US$res)
X-squared = 19.1015, df = 6, p-value = 0.003996

data: (reg12_US$res)
X-squared = 29.306, df = 16, p-value = 0.02195

Residuals:

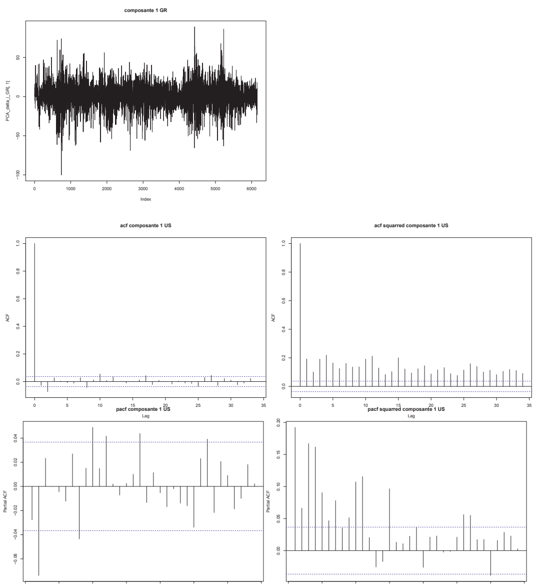




Models details: PCA

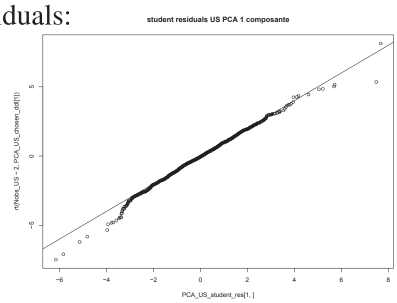
US portfolio

1stcomponent

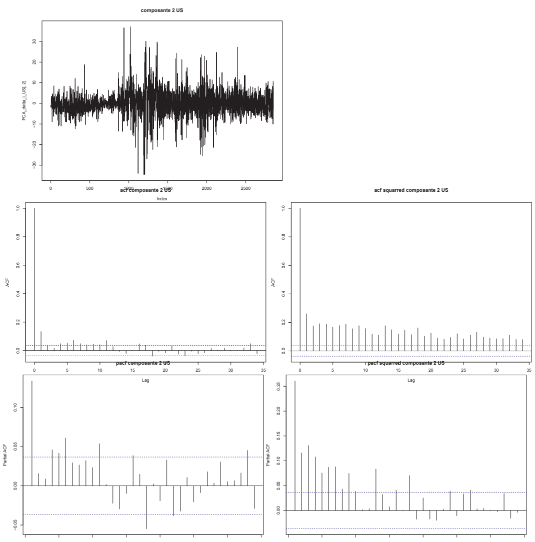


```
Residuals:
    Min      1Q  Median      3Q     Max
-4.98777 -0.60869 0.03562 0.60660 6.23896

Coefficient(s):
   Estimate  Std. Error  t value Pr(>|t|)
a0 197.81437    9.07908   21.788  < 2e-16 ***
a1   0.11931    0.01844    6.470 9.80e-11 ***
a2   0.09637    0.02082    4.628 3.70e-06 ***
a3   0.20542    0.02011   10.214  < 2e-16 ***
a4   0.10627    0.02292    4.637 3.53e-06 ***

Diagnostic Tests:
Jarque Bera Test
data:  Residuals
X-squared = 532.0747, df = 2, p-value < 2.2e-16

Box-Ljung test
data:  (PCA_reg1_US$res)
X-squared = 22.754, df = 6, p-value = 0.0008832

data:  (PCA_reg1_US$res)
X-squared = 34.0138, df = 16, p-value = 0.00541
```

Residuals:

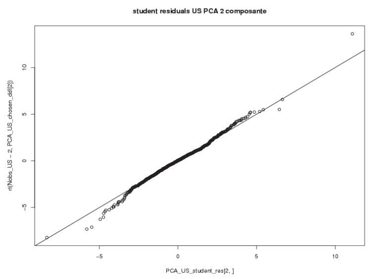


2ndcomponent



```
Residuals:
    Min      1Q  Median      3Q     Max
-6.43568 -0.61590 -0.04715 0.54085 8.49397

Coefficient(s):
   Estimate Std. Error t value Pr(>|t|)
a0  9.70858   0.26916  36.069  <2e-16 ***
a1  0.24830   0.02026  12.253  <2e-16 ***
a2  0.18348   0.01921   9.554  <2e-16 ***
a3  0.15429   0.01843   8.372  <2e-16 ***
a4  0.21366   0.02119  10.085  <2e-16 ***

Diagnostic Tests:
Jarque Bera Test
data:  Residuals
X-squared = 1590.729, df = 2, p-value < 2.2e-16

Box-Ljung test
data:  (PCA_reg2_US$res)
X-squared = 50.9403, df = 6, p-value = 3.045e-09

data:  (PCA_reg2_US$res)
X-squared = 90.1484, df = 16, p-value = 2.349e-12
```

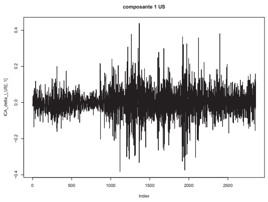
Residuals:

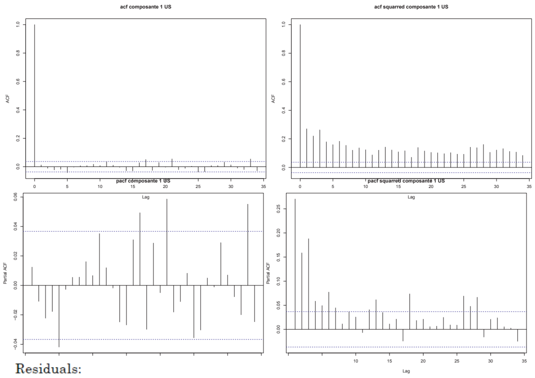


Models details: ICA

US portfolio

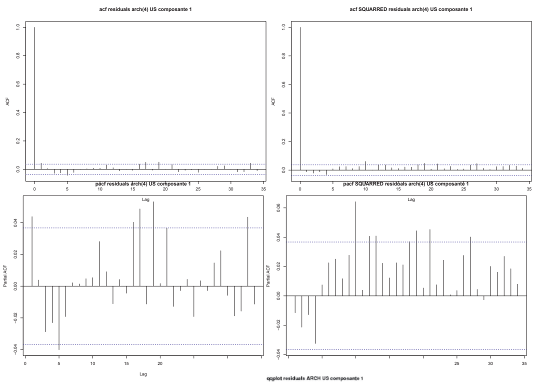
1stcomponent

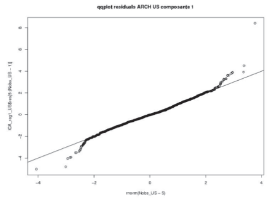




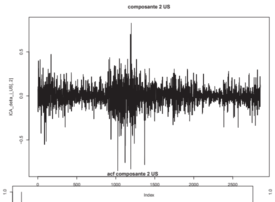
```
Residuals:
     Min       1Q   Median       3Q      Max
-5.01634 -0.62166 -0.03006  0.58960  8.41346

Coefficient(s):
    Estimate  Std. Error  t value Pr(>|t|)
a0 0.0019638   0.0000544   36.102  < 2e-16 ***
a1 0.1982550   0.0236162    8.395  < 2e-16 ***
a2 0.1494380   0.0213470    7.000 2.55e-12 ***
a3 0.1594370   0.0205822    7.746 9.55e-15 ***
a4 0.2042758   0.0225883    9.043  < 2e-16 ***

Diagnostic Tests:
Jarque Bera Test
data:  Residuals
X-squared = 1033.662, df = 2, p-value < 2.2e-16

Box-Ljung test
data:  (ICA_reg1_US$res)
X-squared = 16.8916, df = 6, p-value = 0.00969

data:  (ICA_reg1_US$res)
X-squared = 39.0605, df = 16, p-value = 0.001066
```

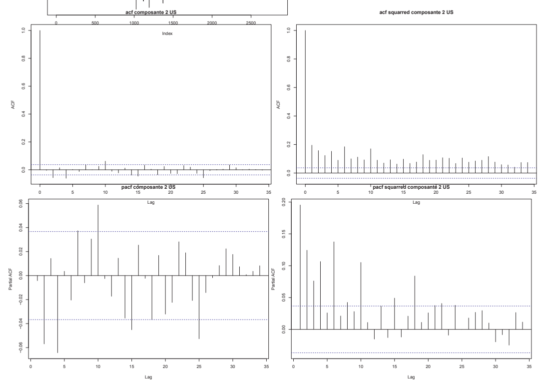
Residuals:





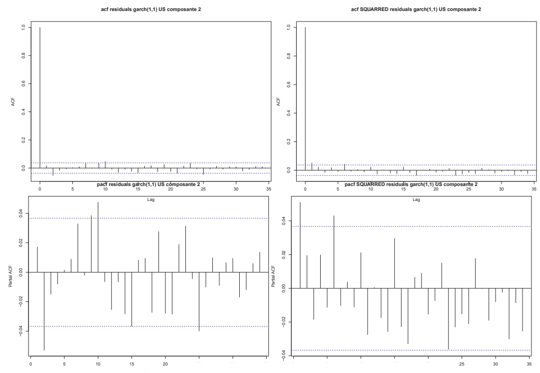
2ndcomponent

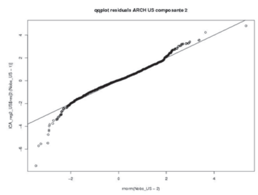




```
Residuals:
      Min        1Q    Median        3Q       Max
-7.447427 -0.557261  0.003816  0.575004  4.808908

Coefficient(s):
    Estimate  Std. Error  t value Pr(>|t|)
a0 5.639e-05   1.068e-05    5.281 1.29e-07 ***
a1 4.946e-02   3.627e-03   13.636  < 2e-16 ***
b1 9.473e-01   3.584e-03  264.332  < 2e-16 ***

Diagnostic Tests:
Jarque Bera Test
data:  Residuals
X-squared = 1337.029, df = 2, p-value < 2.2e-16

Box-Ljung test

data:  (ICA_reg2_US$res)
X-squared = 6.2843, df = 9, p-value = 0.7112

data:  (ICA_reg2_US$res)
X-squared = 19.4421, df = 19, p-value = 0.4288
```

Residuals:

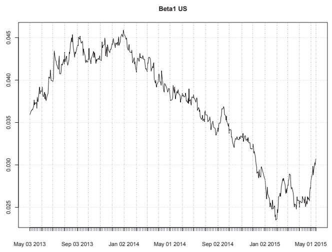




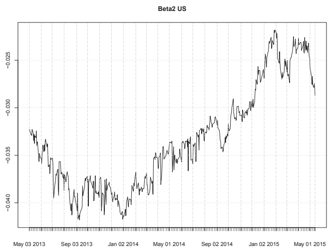
Models details: DNS

US portfolio

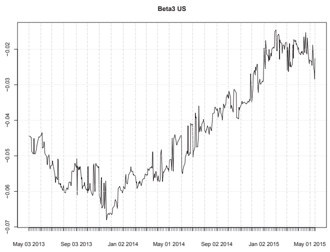
Beta1



Beta2



Beta3

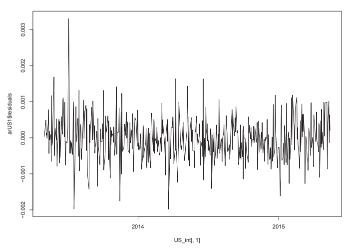


Model:

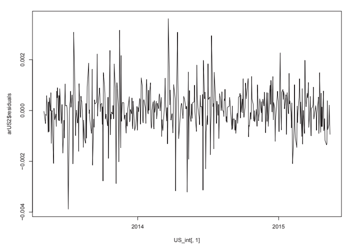
beta	Summary
1 Arima (0,1,1)	Coefficients: ma1 -0.1722 s.e. 0.0444 sigma^2 estimated as 3.333e-07: log likelihood=3019.09 AIC=-6034.17 AICc=-6034.15 BIC=-6025.74
2 Arima (0,1,1)	Coefficients: ma1 -0.3580 s.e. 0.0458 sigma^2 estimated as 7.46e-07: log likelihood=2817.61 AIC=-5631.22 AICc=-5631.2 BIC=-5622.79
3 Arima (1,1,1)	Coefficients: ar1 ma1 0.2681 -0.6780 s.e. 0.0881 0.0677 sigma^2 estimated as 6.285e-06: log likelihood=2284.73 AIC=-4563.45 AICc=-4563.4 BIC=-4550.81

Residuals:

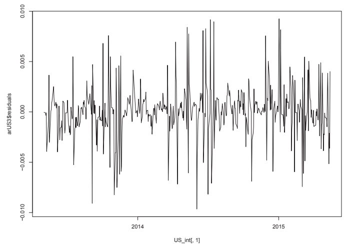
Beta1



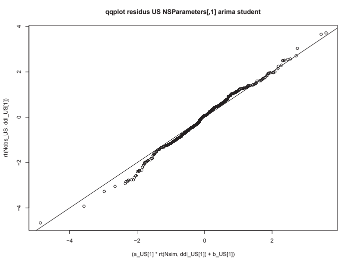
Beta2



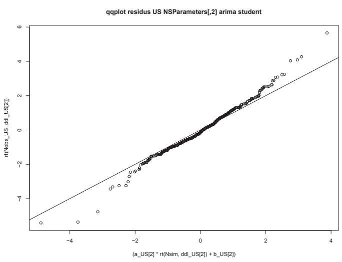
Beta3



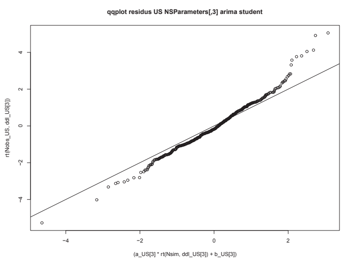
Beta1



Beta2



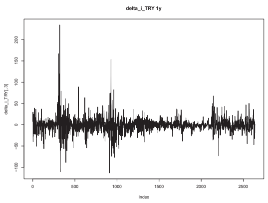
Beta3

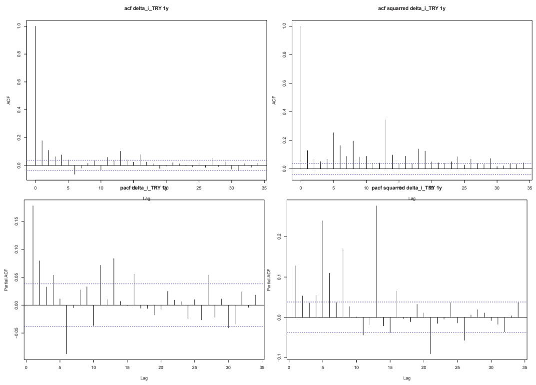


Models details: GARCH

TRY portfolio

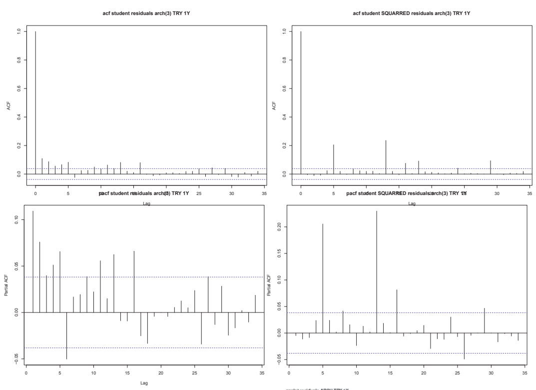
1 year

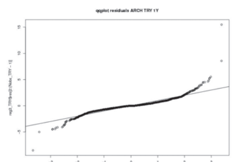




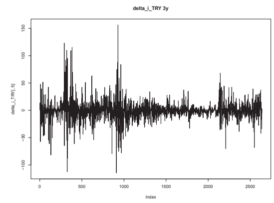
```
Residuals:
    Min      1Q  Median      3Q     Max
-6.4224 -0.4814  0.0000  0.4042  8.5589

Coefficient(s):
    Estimate  Std. Error  t value Pr(>|t|)
a0  72.33999     1.85889    38.92   <2e-16 ***
a1   0.25069     0.01504    16.67   <2e-16 ***
a2   0.13083     0.01133    11.55   <2e-16 ***
a3   0.19328     0.01754    11.02   <2e-16 ***
a4   0.33631     0.01226    27.43   <2e-16 ***

Diagnostic Tests:
Jarque Bera Test
data:  Residuals
X-squared = 8085.155, df = 2, p-value < 2.2e-16

Box-Ljung test
data:  (reg3_TRY$res)
X-squared = 121.9619, df = 6, p-value < 2.2e-16

data:  (reg3_TRY$res)
X-squared = 166.7075, df = 16, p-value < 2.2e-16
```

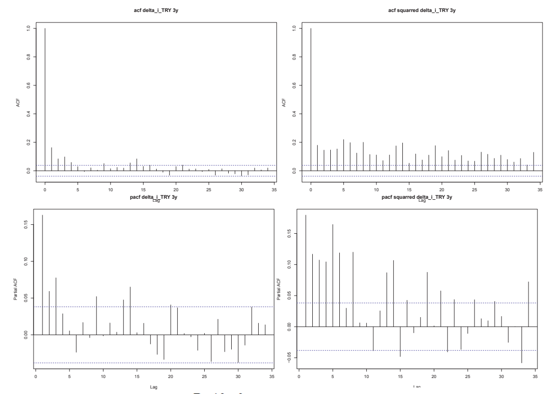
Residuals:





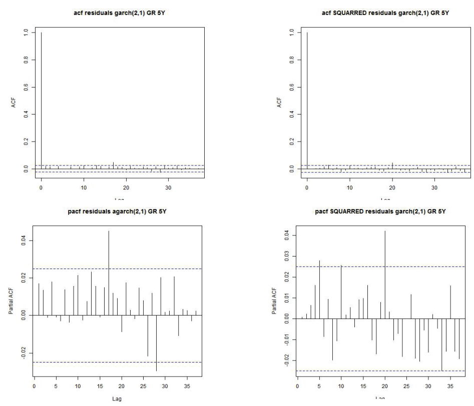
5 years

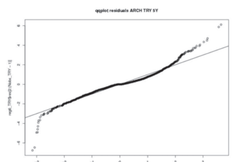




```
Residuals:
    Min      1Q  Median      3Q     Max
-7.9270 -0.4634  0.0000  0.3702  8.9020

Coefficient(s):
    Estimate  Std. Error  t value Pr(>|t|)
a0  71.75976     2.13781   33.567   <2e-16 ***
a1   0.33283     0.01620   20.539   <2e-16 ***
a2   0.13131     0.01326    9.900   <2e-16 ***
a3   0.14275     0.01594    8.957   <2e-16 ***
a4   0.35127     0.01540   22.806   <2e-16 ***

Diagnostic Tests:
Jarque Bera Test
data:  Residuals
X-squared = 9157.636, df = 2, p-value < 2.2e-16

Box-Ljung test
data:  (reg5_TRY$res)
X-squared = 100.1548, df = 6, p-value < 2.2e-16

data:  (reg5_TRY$res)
X-squared = 126.5857, df = 16, p-value < 2.2e-16
```

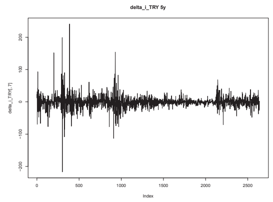
Residuals:

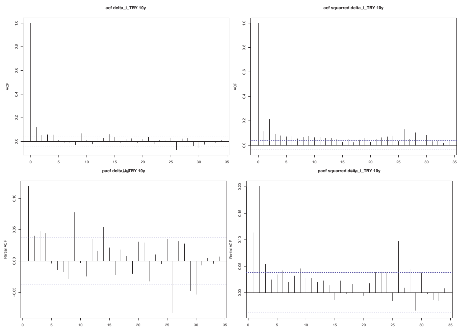




TRY portfolio

10 years





Residuals:
Min 1Q Median 3Q Max
-7.5261 -0.4382 0.0000 0.3843 12.1662

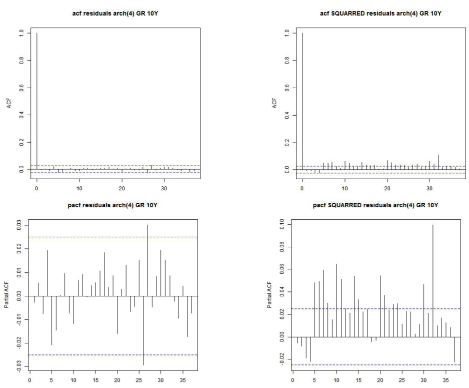
Coefficient(s):
Estimate Std. Error t value Pr(>|t|)
a0 91.494182 1.970766 46.426 < 2e-16 ***
a1 0.267261 0.017024 15.699 < 2e-16 ***
a2 0.080495 0.013275 6.064 1.33e-09 ***
a3 0.399563 0.008781 45.505 < 2e-16 ***
a4 0.170342 0.012950 13.154 < 2e-16 ***

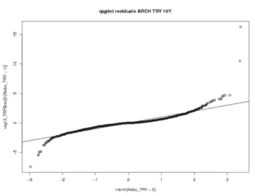
Diagnostic Tests:
Jarque Bera Test
data: Residuals
X-squared = 39156.89, df = 2, p-value < 2.2e-16

Box-Ljung test
data: (reg7_TRY$res)
X-squared = 74.6081, df = 6, p-value = 4.619e-14

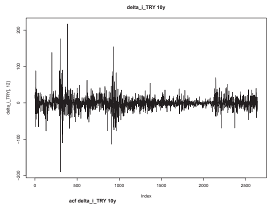
data: (reg7_TRY$res)
X-squared = 88.3281, df = 16, p-value = 5.078e-12

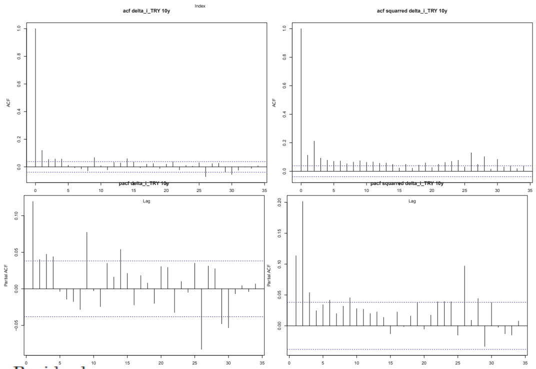
Residuals:





15 years





Residuals:
Min 1Q Median 3Q Max
-7.2964 -0.4496 0.0000 0.3881 10.9646

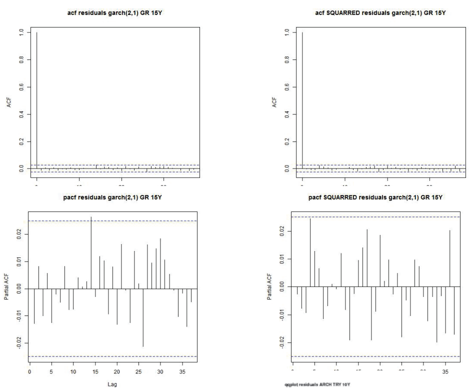
Coefficient(s):
Estimate Std. Error t value Pr(>|t|)
a0 1.101e+02 2.155e+00 51.057 < 2e-16 ***
a1 2.304e-01 1.590e-02 14.490 < 2e-16 ***
a2 6.183e-02 1.264e-02 4.892 9.98e-07 ***
a3 2.905e-01 8.023e-03 36.213 < 2e-16 ***
a4 1.540e-01 1.301e-02 11.838 < 2e-16 ***

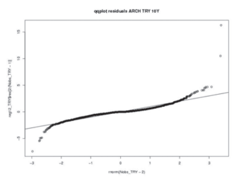
Diagnostic Tests:
Jarque Bera Test
data: Residuals
X-squared = 22923.63, df = 2, p-value < 2.2e-16

Box-Ljung test
data: (reg12_TRY$res)
X-squared = 66.3243, df = 6, p-value = 2.314e-12

data: (reg12_TRY$res)
X-squared = 76.615, df = 16, p-value = 6.739e-10

Residuals:

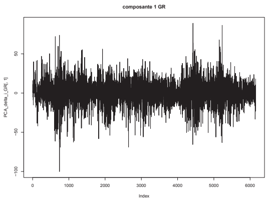


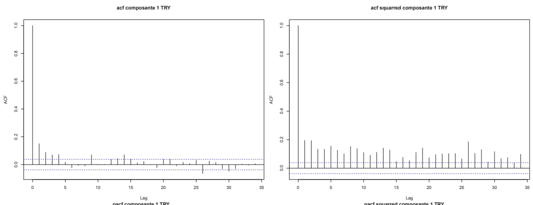


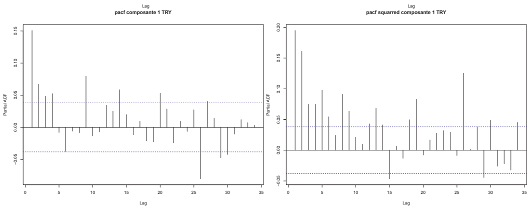
Models details: PCA

TRY portfolio

1stcomponent

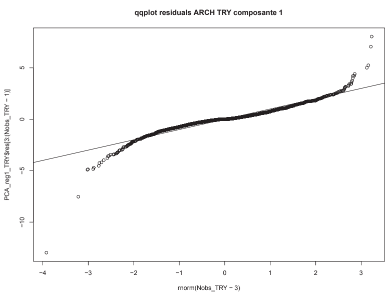




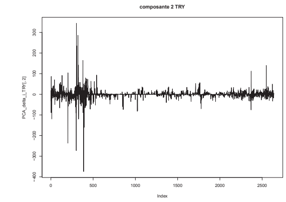


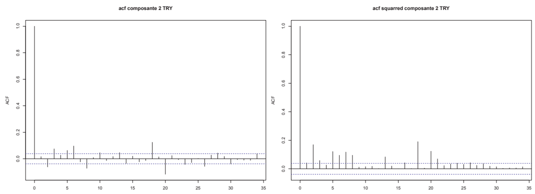

```
Residuals:
    Min      1Q  Median      3Q     Max
-7.7076 -0.4087  0.0000  0.4673  8.6312

Coefficient(s):
    Estimate  Std. Error  t value Pr(>|t|)
a0 1.242e+03   2.406e+01   51.621  < 2e-16 ***
a1 2.685e-01   1.689e-02   15.900  < 2e-16 ***
a2 5.734e-02   1.299e-02    4.414 1.02e-05 ***
a3 2.098e-01   8.716e-03   24.069  < 2e-16 ***
a4 1.953e-01   1.418e-02   13.781  < 2e-16 ***

Diagnostic Tests:
Jarque Bera Test
data:  Residuals
X-squared = 8622.912, df = 2, p-value < 2.2e-16

Box-Ljung test
data:  (PCA_reg1_TRY$res)
X-squared = 92.2177, df = 10, p-value = 1.998e-15

data:  (PCA_reg1_TRY$res)
X-squared = 109.5026, df = 20, p-value = 2.42e-14
```

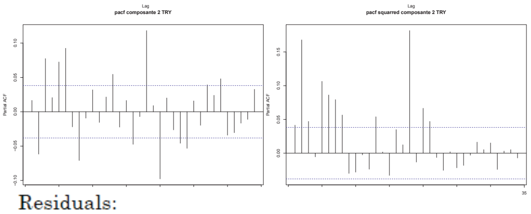
Residuals:



2ndcomponent

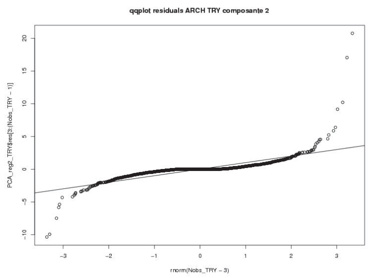







```
Residuals:
    Min      1Q  Median      3Q     Max
-7.7076 -0.4087  0.0000  0.4673  8.6312

Coefficient(s):
    Estimate  Std. Error  t value Pr(>|t|)
a0 1.242e+03   2.406e+01   51.621  < 2e-16 ***
a1 2.685e-01   1.689e-02   15.900  < 2e-16 ***
a2 5.734e-02   1.299e-02    4.414 1.02e-05 ***
a3 2.098e-01   8.716e-03   24.069  < 2e-16 ***
a4 1.953e-01   1.418e-02   13.781  < 2e-16 ***

Diagnostic Tests:
Jarque Bera Test
data:  Residuals
X-squared = 8622.912, df = 2, p-value < 2.2e-16

Box-Ljung test
data:  (PCA_reg1_TRY$res)
X-squared = 92.2177, df = 10, p-value = 1.998e-15

data:  (PCA_reg1_TRY$res)
X-squared = 109.5026, df = 20, p-value = 2.42e-14
```

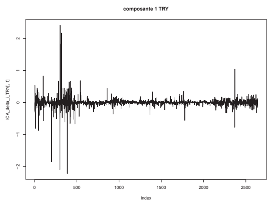

Residuals:

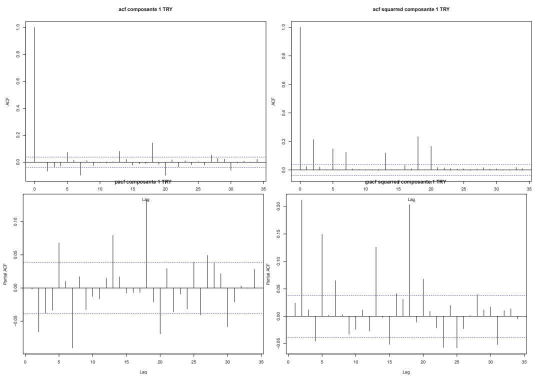


Models details: ICA

TRY portfolio

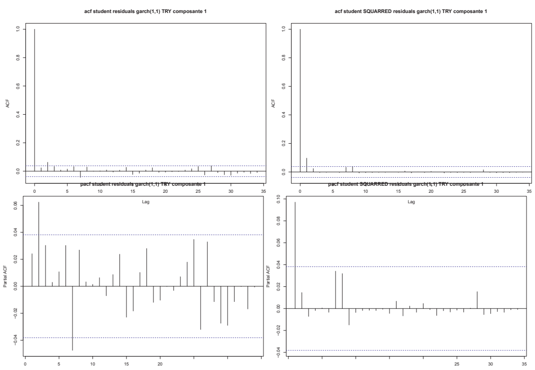
1stcomponent

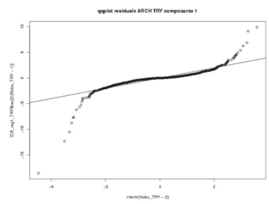




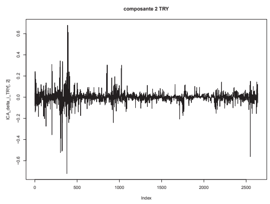
```
Residuals:
    Min      1Q  Median      3Q     Max
-6.3688 -0.4431  0.0000  0.3919  9.1891

Coefficient(s):
    Estimate  Std. Error  t value Pr(>|t|)
a0 5.169e-05   3.708e-06    13.94   <2e-16 ***
a1 2.760e-01   8.173e-03    33.77   <2e-16 ***
b1 7.697e-01   5.587e-03   137.76   <2e-16 ***

Diagnostic Tests:
Jarque Bera Test
data:  Residuals
X-squared = 9589.747, df = 2, p-value < 2.2e-16

Box-Ljung test
data:  Squared.Residuals
X-squared = 0.0144, df = 1, p-value = 0.9044

data:  (ICA_reg1_TRY$res)^2
X-squared = 6.5009, df = 10, p-value = 0.7716
```

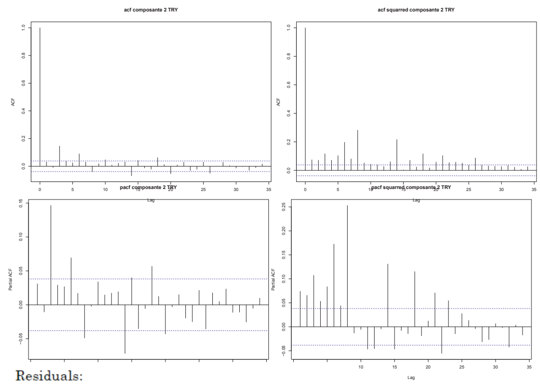
Residuals:





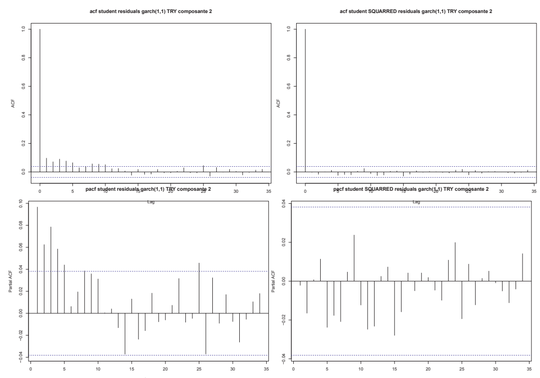
2ndcomponent

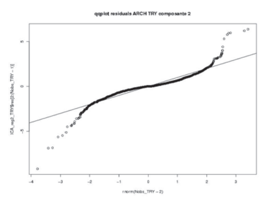




```
Residuals:
    Min      1Q  Median      3Q     Max
-9.4367 -0.1065  0.0000  0.1611 23.0648

Coefficient(s):
    Estimate  Std. Error  t value Pr(>|t|)
a0 8.960e-05   2.628e-06    34.09   <2e-16 ***
a1 7.350e-02   2.741e-03    26.82   <2e-16 ***
b1 9.211e-01   2.075e-03   443.81   <2e-16 ***

Diagnostic Tests:
Jarque Bera Test
data:  Residuals
X-squared = 1584885, df = 2, p-value < 2.2e-16

Box-Ljung test
data:  Squared.Residuals
X-squared = 0.0244, df = 1, p-value = 0.8758

data:  (ICA_reg2_TRY$res)^2
X-squared = 0.2223, df = 10, p-value = 1
```

Residuals:

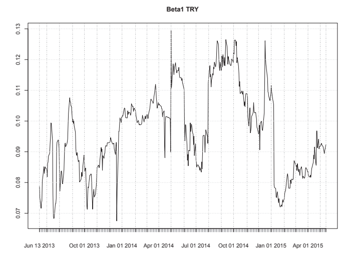




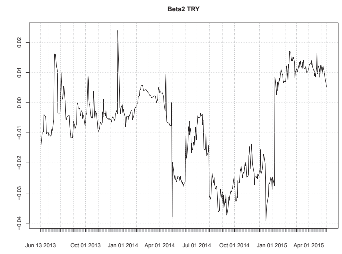
Models details: DNS

TRY portfolio

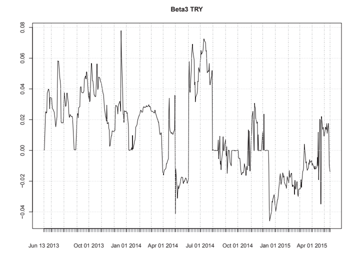
Beta1



Beta2



Beta3

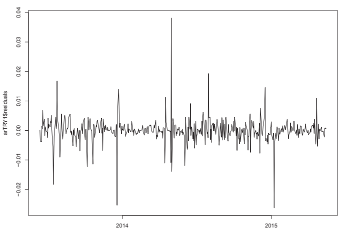


Model:

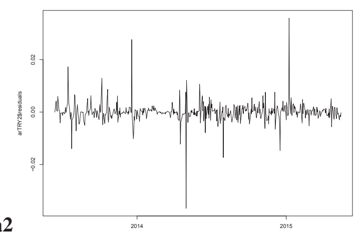
beta	Summary
1 Arima (0,1,1)	Coefficients: ma1 -0.1250 s.e. 0.0444 sigma^2 estimated as 1.681e-05: log likelihood=2038.85 AIC=-4073.7 AICc=-4073.67 BIC=-4065.27
2 Arima (1,1,1)	Coefficients: ar1 ma1 0.5057 -0.6884 s.e. 0.1541 0.1307 sigma^2 estimated as 1.569e-05: log likelihood=2056.08 AIC=-4106.15 AICc=-4106.11 BIC=-4093.51
3 Arima (0,1,1) (3,1,2)	Coefficients: ma1 -0.2381 s.e. 0.0480 sigma^2 estimated as 9.49e-05: log likelihood=1606.17 AIC=-3208.34 AICc=-3208.32 BIC=-3199.92

Residuals:

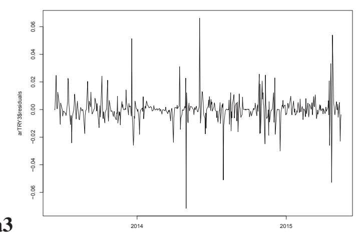
Beta1



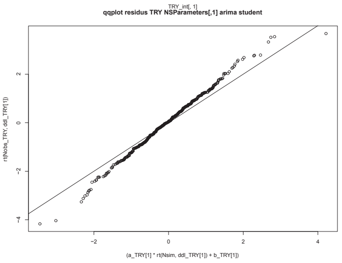
Beta2



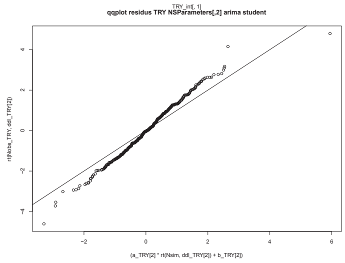
Beta3



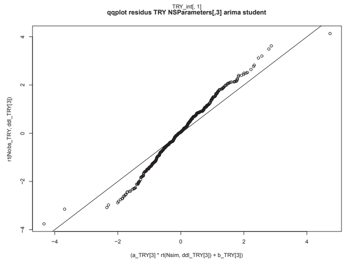
Beta1



Beta2



Beta3



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