VIETNAM NATIONAL UNIVERSITY - HO CHI MINH CITY
INTERNATIONAL UNIVERSITY
DEPARTMENT OF MATHEMATICS

GRADUATION THESIS

Exposure At Default under Basel II and III

Author:
Dinh Khanh Duy

Supervisor:
Dr. Duong Dang Xuan Thanh

A thesis submitted in partial fulfillment of the requirements for the degree of **Bachelor of Science** in
FINANCIAL ENGINEERING & RISK MANAGEMENT

Ho Chi Minh City, Vietnam
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By

Dinh Khanh Duy

Submitted to Department of Mathematics,

International University, Ho Chi Minh City in partial fulfillment of requirements for the degree of bachelor of science in

Financial Engineering and Risk Management

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Signature of Student: ______________________________

Dinh Khanh Duy

Certified by: ______________________________

Duong Dang Xuan Thanh, Dr.

Thesis Supervisor

Approved by: ______________________________

Assoc. Prof. Pham Huu Anh Ngoc

Head of Department of Mathematics

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Exposure At Default under Basel II and III

Dinh Khanh Duy

May 30, 2017

Abstract

The main reason for the financial crisis 2008 in the worldwide banking systems was the ignorance of the counterparty credit risk (CCR). In response, the Basel Committee on Banking Supervision introduced a new credit valuation adjustment (CVA) capital framework to mitigate this risk and also strengthen capital profile of banks. The objective of the thesis was to investigate an approach to an exposure at default (EAD), which is the most essential input for many capital frameworks in Basel regulations, especially for the CVA capital one. After a few chapters providing some adjacent conceptual background, the main consideration was about the calculation of the EAD for the OTC interest rate swap (IRS) contracts portfolio under current exposure method. The EAD calculation was totally executed by an automatic calculator, which was self-programmed by the thesis' author in R programming language. Also, a valuation of mark-to-market value of the IRS and the construction of a zero-curve for discounting swap's cash flows were fully analysed. The data sample for EAD calculation was a generated portfolio of the OTC IRS contracts referenced by some characteristics of the standardized contracts in the US exchange. Using the market data of USD-Libor spot rate and Eurodollar Futures (April 27, 2017), I could construct the zero-curve by combining the linear interpolation and bootstrapping methods for specifying a mark-to-market value of each swap contract, and hence the EAD. Finally, the benefit of netting and collateral on EAD value was proven by experimental results and comparisons.

Keywords: *Basel III, Credit Valuation Adjustment, Counterparty Credit Risk, Exposure at Default, Current Exposure Method, OTC Derivatives, Interest Rate Swap, Netting, Collateral.*

Declaration of Authorship

I, Dinh Khanh Duy, declare that this report titled, “Exposure At Default under Basel II and III” and the work presented in it are my own. I confirm that:

- This work was done wholly or mainly while in candidature for a research degree at this University.
- Where any part of this report has previously been submitted for a degree or any other qualification at this University or any other institution, this has been clearly stated.
- Where I have consulted the published work of others, this is always clearly attributed.
- Where I have quoted from the work of others, the source is always given. With the exception of such quotations, this report is entirely my own work.
- I have acknowledged all main sources of help.
- Where the report is based on work done by myself jointly with others, I have made clear exactly what was done by others and what I have contributed myself.

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List of Abbreviation

BCBS	Basel Committee on Banking Supervision
CCF	Credit Conversion Factor
CCL	Contingent Credit Lines
CCR	Counterparty Credit Risk
CE	Current Exposure
CEM	Current Exposure Method
CSA	Credit Support Annex
CVA	Credit Valuation Adjustment
EAD	Exposure At Default
EE	Expected Exposure
EEE	Effective Expected Exposure
EEPE	Effective Positive Expected Exposure
EPE	Expected Positive Exposure
IMM	Internal Model Method
IRS	Interest Rate Swap
ISDA	International Swaps & Derivatives Association
LGD	Loss-given-default
LIBOR	London Interbank Offered Rate

MNA	Master Netting Agreement
MTM	Mark-to-market
NGR	Net-to-Gross ratio
NIMM	Non-Internal Model Method
OTC	Over-The-Counter
PD	Probability of Default
PFE	Potential Future Exposure
PD	Probability of Default
SA-CCR	Standardized Approach for Counterparty Credit Risk
SM	Standardized Method
SFT	Security Financing Transactions

Chapter 1

Introduction

1.1 Historical Overview

During the past decades, the banking systems in all over the world have encountered various lessons stemming from last financial crisis in 2008. One of the most valuable experiences shared by banks is the inefficient management of counterparty credit risk (CCR)[1], especially after the collapse of Bear Sterns and the bankruptcy of the giant Lehman Brother. The Financial Crisis Inquiry Commission was assigned to investigate the origination of the financial crisis in the United States. Finally, it concluded that "the so-called over-the-counter (OTC) derivatives were the main contributing factor to the crisis and these type of contracts made the damages of the evolving debt crisis even worse by fueling the destruction process of the already fragile house of cards" [2]. The opacity of the OTC markets means that they are lack of transparency and accountability. And even if they have been standardized and regulated in the market exchange, this has not been conducted to a comprehensive way yet.

Before the crisis began, it had become all too obvious that some biggest banks and financial institutions were considered as "too big to fail". The concept indicates that certain institutions are so enormous and so interconnected that their collapse

[1]The risk associated to each party within a financial contract that the other counterparty will default or be unable to honor the contractual obligations.

would possibly lead to tremendous consequences to all economic systems. And hence in case of default, the government must send financial bailouts to rescue them. It therefore created moral hazard issues as big counterparties were considered risk-free and therefore their probability of default (PD) was assigned a zero. Once the crisis hit; however, the collapses of some giants in the financial sector was a wake-up call for all participants in the financial market. The Lehman default was a typical example to illustrate tragic consequences of this blind faith. In September 2008, all the major credit rating agencies-Moody's, Fitch, Standard & Poor's measured at least an A rating[2] right up to the time of Lehman's collapse [9]. Based on these ratings, most counterparties usually ignored the counterparty risk to Lehman Brothers and therefore underestimated some risk mitigation such as collateral to protect them in case of Lehman's default. As the worse case happened, these banks did not prepare enough capital to absorb their losses on marked to market position and thus encountered liquidity or even insolvency issues.

1.2 Regulatory Reform and Advent of Credit Valuation Adjustment

It is urgent to produce a massive shift in the regulatory oversight for the banking system and large financial firms. Rules are forced to be comprehensively improved and much tighter procedures for banks and OTC derivatives transactions to perform a more reliable and transparent financial market environment, and hence to prevent other impending crises. In response, one of the increased levels of regulations in recent years is the capital requirement. Capital acts as a buffer to alleviate unexpected losses occurring through tempestuous periods. Since the Basel I Accord[3], banks have already been obliged to hold capital against credit risk; however, due to the insufficiency of Basel I rules in risk-sensitivity, banks certainly gained wrong incentives from the allowance to lessen their regulatory capital requirement without

[2]It is considered a very safe institution.

[3]Basel Accord, *International Convergence of Capital Measurement and Capital Standards, 1988.*

actually minimize the transaction risks they were exposing. To handle this issue, an updated Capital Framework in Basel II (BCBS, 2006) was implemented, enabling some sophisticated banks to apply internal methods (once approved by supervisory authorities) for measuring credit exposure as well as other risk factors such as PD and Loss given default[4]. Under the Basel II framework; however, banks were only instructed to hold capital reserve against the default of their counterparties in the trading book, yet there was no requirement to capitalize against the CVA losses[5].

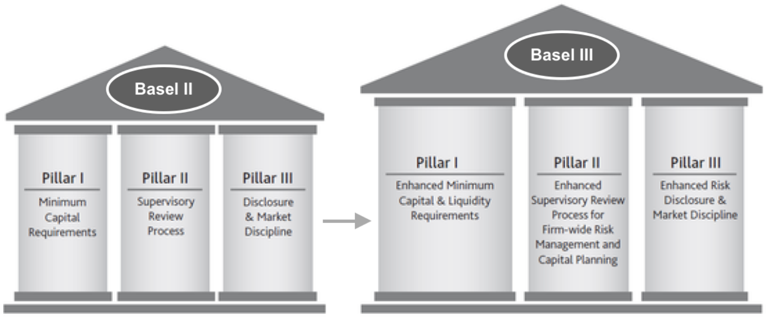


Figure 1.1

Management enhancement from Basel II to Basel III.

Obviously, the counterparty credit risk framework under Basel II was only designed to capitalize for actual default and migration risk rather than the potential accounting losses that can arise from CVA [15]; hence, ignored the current and potential mark-to-market (MTM) losses[6] due to a variability of underlying assets through a time of contract. As the financial crisis occurred, approximately two thirds of counterparty risk losses were contributed by MTM losses and only one third were from actual default. To address this gap in the framework, the BCBS established the new CVA capital charge as part of Basel III to require banks to hold an addition capital-CVA capital to absorb the CVA risk. The CCR under Basel III is restructured as

[4]Loss given default (LGD) is the share of asset financial institution loses when a counterparty defaults on a contract's payment.

[5]The difference between the risk-free value of a portfolio and the market value of that portfolio, corresponding to the possible downgrade of a counterparty's credit profile.

[6]The losses in an underlying asset's value which was caused mainly by a movement in a current market price.

follows [5]:

$$\text{CCR (Basel III)} = \text{Default risk (Basel II)} + \text{CVA risk (Basel III)}. \qquad (1.2.1)$$

An advent of CVA is a tool for adjust the fair value (or price) of derivative contracts to deal with MTM losses and CCR. Thus, CVA is also known as the price of CCR. This price depends on counterparty credit spreads[7] as well as on the market risk factors that impact derivatives' value. The purpose of the Basel III CVA capital charge is to capitalize uncertainties of future changes in CVA. The standardized formula for CVA capital (denoted K) under Basel III is [9]:

$$K = 2.33\sqrt{h}\sqrt{\left(\sum_i 0.5X_i\right)^2 + \sum_i 0.75X_i^2}, \qquad (1.2.2)$$

where 2.33 is z-score at 99% confidence level under the Standard Normal distribution ($z_{0.01} = 2.33$), h is one-year risk horizon, and X_i is the variability in the CVA for the i^{th} counterparty.
Also X_i represents the movement in CVA, which is the products of three components [9]:

$$X_i = w_i \times M_i \times EAD_i, \qquad (1.2.3)$$

where:

- w_i: a weight deriving from the credit rating of the counterparty i. This can be illustrated in the **Table 1.1**.
- M_i: the effective maturity.
- **EAD_i: the total counterparty i's exposure at default including the effect of netting and collateral. This parameter is the main point of the thesis.**

[7]These spreads are mainly based on a deterioration of counterparty's credit quality.

Table 1.1

A converted weight with respect to the credit rating of a financial institution.

Rating	Weight
AAA	0.7%
AA	0.7%
A	0.8%
BBB	1.0%
BB	2.0%
B	3.0%
CCC	10.0%

1.3 Objective of Study

For computing the regulatory CVA at counterparty level, there are many risk parameters need precisely estimating and computing such as Loss-given-default, Probability of Default and Effective maturity. The scope of thesis; however, only concentrates on the most essential component in the CVA computation, which is the **Exposure at default**.

1.4 EAD - Exposure At default

It is essential for all financial institutions to manage the Exposure at Default. In addition, the EAD, along with other risk parameters such as LGD and PD, is used to calculate the regulatory capital against credit risk through the time of transaction. The BIS defines EAD as the estimated amount which the bank may be exposed to its counterparty in the event of possible default. EAD is approached through various methods, which are described in detail below.

1.5 Methods for Exposure At Default

Under Basel II framework (BCBS, 2006), banks can decide whether to select the regulatory framework or own methods to compute EAD within a single counterparty. In addition, EAD is measured at the netting set level[8] and can be used for some type of derivative instruments such as interest rate swap, caps, floors, foreign exchange currencies, equity swaps, etc.

Three common methods for calculating the EAD under Basel standards are:

- Current exposure method (CEM)
- Standardized method (SM)
- Internal model method (IMM)

CEM and SM are often considered the non internal model methods. They provide simplicity and flexibility for those banks that could not afford for the sophisticated exposure-model internally. The IMM, on the other hand, was introduced later in Basel III and also requires sophisticated modeling for all the underlying risk aspects; therefore, IMM approval is costly to usage and maintenance. Due to these flaws, IMM approval for counterparty risk is globally acquired by only largest banks in the world.

[8]"A group of derivative contracts transacted with a single counterparty subject to a legally enforceable bilateral netting agreement that satisfies some consistent standards in Annex 4 of BCBS, 2006" [9].

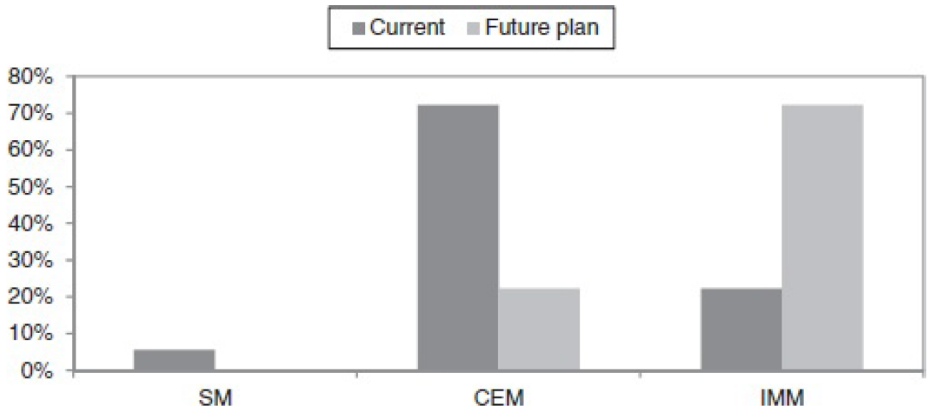


Figure 1.2

Market practice for EAD approach.

Source: Deloitte CVA survey.

From **Figure 1.2**, most banks prefer CEM and IMM to SM. The SM is unusual since some regulators such as US and Canada, have excluded it. For this reason, the standardized method is out of the scope of this thesis and only CEM and IMM are studied (in **Chapter 4** and **5**).

1.6 Thesis Outline

In **Chapter 2**, the overview about some relevant papers and books associating with EAD topic will be given.

Chapter 3 will present readers conceptual background about the counterparty credit risk, OTC derivatives market as well as two mitigating tools of credit risk. Once we are clear about these definition, we can move to the next following chapter to study about two frameworks in Basel Accord for EAD calculation.

After that, **Chapter 4** and **5** will consider about these frameworks: Current exposure method (CEM) and Internal model method (IMM). Next, **Chapter 6** will present about the EAD calculation for the OTC interest rate swap contracts portfolio. In addition, a valuation of interest rate swap, a construction of zero curve and a sample portfolio data will be discussed in detail.

Finally, some conclusions including limitation and recommendation within this topic area will be stated in **Chapter 7**.

Chapter 2

Literature Review

The theoretical base of models in this paper originated from a book titled *“xVA Challenge”* [9] of *Dr Jon Gregory* (2015). In this book, he wrote very details about the EAD concept as well as approaches to acquire EAD for counterparty credit risk. Moreover, many criticisms about each method to calculate EAD were included as well. John also introduced a book named *“Counterparty Credit Risk and Credit Value Adjustment: A Continuing Challenge for Global Financial Markets”* [8] in 2012, which provides many useful methods for quantifying credit exposure such as Add-ons, Semi-analytical methods, Mote Carlo simulation...Based on these methods, some essential inputs like exposure profile can be derived to compute EAD.

According to the paper of *Orlando Giuseppe and Hartel Maximilian* (2014) [16], a new approach to EAD combined between the simplest Current Exposure Method (CEM) and many sophisticated approaches was introduced. A purpose of their studies is to consider the impact of the liquidity risk on collateral requirements. In particular, they explained how to approach the netting exposure for each counterparty and collateral agreements. Furthermore, they proposed the new concept of potential future exposure and credit loss as well as default probability as the result of a Poisson process. With many advanced developments and new concepts, they expected to apply this approach as a refinement of liquidity risk measurement in order to enhance the management of liquidity congruence in banks' balance sheet, particularly under some stressed market circumstances.

At the same year in 2014, a paper from *Jonsson, Sara, and Beatrice Rönnlund* [11] stated the differences in calculation of EAD between the CEM and SA-CCR for OTC derivative contracts. After applying both methods to obtain EAD on real portfolio of a Swedish commercial bank, the results indicated that SA-CCR received a lower EAD than CEM due to the netting efficiency but higher EAD when no netting permission. Also, many foreign derivative exchanges has reported to obtain lower EAD in both cases of with and without netting approval under SA-CCR. An improvement from CEM to SA-CCR could facilitate financial institutions to manage the regulatory capital and allocate it more effectively.

In terms of EAD for loans and credit risk, the two journals of *Michael Jacobs Jr. and Pinaki Bag* (2010) [14] [1] computed the EAD for Contingent Credit Lines (CCL). Since a major challenge with unsuitability of external data and inconsistent internal data with partial draw-downs was faced by most risk managers and regulators in managing CCL portfolios, they tried to set up an simple to implement, practical and parsimonious but accurate model to assess the exposure distribution of CCL portfolios. An algorithm based on basic Credit Risk and Fourier Transforms that Jacobs and Bag utilized was arrived at a probability distribution of portfolio usage and portfolio segments.

The studies of *Mindy Leow, Jonathan Crook* (2015) [13] and *Edward N. C. Tong, Christophe Muesb, Iain Brownc, Lyn C. Thomasb* [19] (2016) also contributed many useful tools to measure credit card EAD. Leow and Jonathan introduced a new mixture model for estimation of EAD at the level of counterparty. They estimate the various exposures, not only in the event of default but at any time during the maturity of a loan as well. Additionally, it is theorized that the outstanding exposure on a credit card is a function of the credit consumption by the borrower and subject to the credit line extended by loan issuer. Consequently, banks are available to predict more accurately for outstanding balance at any time during the effective loan maturity.

Besides, the EAD models excluding Credit Convension Factor (CCF) was introduced by Edward, Christophe, Iain and Lyn in a year later. As the challenges with the CCF's bimodal distribution from 0 to 1, there has been criticism on the suitability of the CCF for EAD model. In their study, they found an alternative EAD model which ignores the distribution of CCF and targets the EAD distribution straightly. A tested data sample was a credit card portfolio of a UK bank . Applying a mixture model with the zero-adjusted γ-distribution on this sample and comparing the performance to some benchmark CCF models, the result indicated that zero-adjusted γ model calibrates the EAD more accurately than the traditional models. As the result, this model is very prospective to replace the benchmark CCF models or both could be incorporated.

Chapter 3

Conceptual Background

3.1 CCR - Counterparty Credit Risk

The unique characteristic about CCR is that it inherits both market and credit risks. In order to interpret the counterparty credit risk, each type of risk will be defined and also how they relate to each other.

Firstly, credit risk involves with losses that a counterparty could not pay its contractual obligation leading to the default event. In practice, credit risk is most associated with lending risk where the loss settlement amount is already determined throughout the effective lending period. In the context of lending risk, only one party (lender) exposes to the credit risk and it is obviously unilateral.

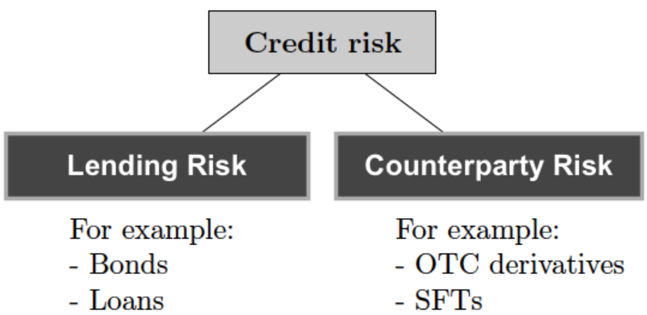


Figure 3.1

Sub-type of credit risk.

On the other hand, CCR is bilateral as both parties could encounter credit risk and even market risk[1] depending on a variability of underlying assets stated in the contract throughout the holding period. Furthermore, CCR exists only when two private counterparties negotiate bilaterally some derivative contracts, which are often zero-sum instruments[2]. These transactions mainly happen in the Over-the-counter (OTC) market. Derivative instruments in the exchange market, on the other hand are not incurred the CCR as derivative exchanges have a central counterparty clearing function which imposes some mitigating tools such as collateral and asset-backed securities, and therefore reducing the CCR.

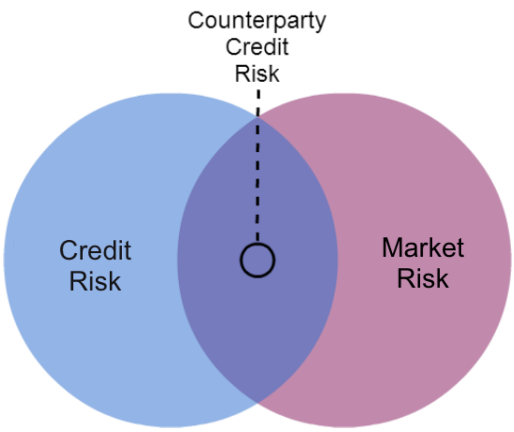


Figure 3.2

Counterparty credit risk is the intersection area between the market and credit risk.

[1]The risk of losses due to fluctuations in market positions is classified as market risk (systematic risk).

[2]Contracts in which positive value increase to one party is a loss to the other.

3.2 OTC Derivatives Market

Nowadays, the major part contributing to banks' CCR is mainly built up by OTC derivatives. The opacity and complicated structure of these instruments requires more precise and comprehensive computation than other type of securities.

3.2.1 Exchange Traded and OTC Derivatives

On the one hand, within the exchange-traded market, many derivative products are standardized and guaranteed by one financial center, which holds an exchange. The essential function of exchange is promoting market efficiency and liquidity for all participants in the market. Moreover, it not only provides an efficient price discovery[3] but also offers a tools of mitigating counterparty risk. These insurances help to guarantee market's performance and also reduce the risk for the investors.

On the other hand, OTC derivatives are prone to be less standardized structures and usually traded privately within two parties. As these transactions are just private trading, the transaction records are rarely reported as a part of any protection program. Thus each party incurs many potential risks including credit risk, market risk and especially counterparty credit risk. Based on the statistical data and reports of BCBS, OTC derivatives today constitute a major proportion of the CCR.

[3]The act of determining the price of some assets in a exchange market through the equilibrium point of demand and supply.

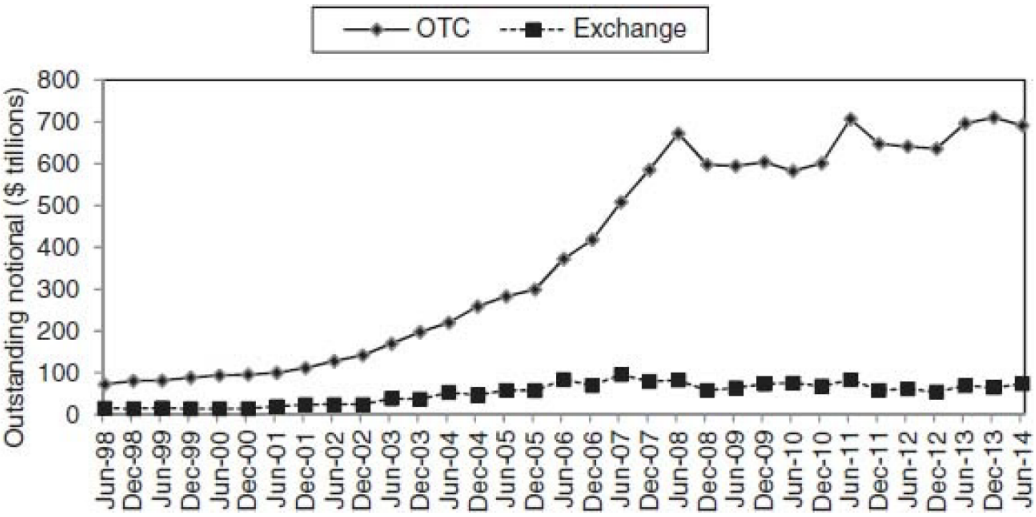


Figure 3.3

The record of total outstanding notional amount of exchange-traded vs OTC derivatives transactions 1998-2014.

Source: BIS.

3.2.2 Products of OTC Derivatives Market

According to BIS statistics, there is the substantial increase of the OTC market in the last decade. **Figure 3.4** obviously shows that the interest rate derivatives contribute to the major body of the value in the OTC market.

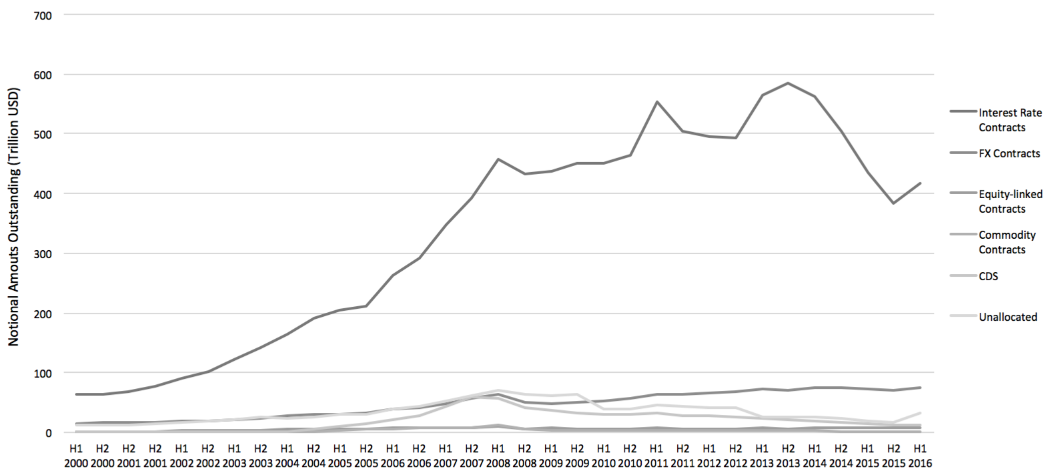


Figure 3.4

The record of total global trade in OTC derivatives 2000-2015, showing the total amounts of the different derivatives products.

Source: BIS.

In this thesis, the **interest rate swap** (IRS) will be selected as an sample for the computation of EAD.

3.2.3 Challenges in Computation of CCR for OTC Derivatives

First of all, computing the potential exposure is an arduous task. As the contract's future values is a function of the undetermined future value of the underlying asset(s), such future values are impossible to be estimated with a 100% degree of certainty. These potential values are essential for financial institutions to allocate their funds for CVA capital charge.

Secondly, OTC derivative contract can be either an asset or a liability of the firm, depending on the sign of its contract's MTM value. Let's take one IRS contract as an example.

Example: IRS CONTRACT BETWEEN APPLE AND HSBC

Consider Apple company are now issuing a 3.45% fixed-rate bond in the market. However, the Apple's management expects that it could achieve a better cash flows from a floating rate. To pursue this strategy, Apple can enter into a interest rate swap contract ($1000 in notional amount) with a counterparty bank (i.e., HSBC) in which bank pays a floating rate to the Apple in exchange for a fixed rate. Apple and HSBC both agree to select the preferred floating-rate index, which is normally a LIBOR for a 1-, 3- or 6-month maturity. At each settlement date of the contract, Apple then receives LIBOR rate plus (or minus) a constant spread (i.e., 10 basis point) which reflects both its financial conditions and credit rating[a].

At the initial settlement day, this swap has a zero value as it needs to be fair for both parties. During the lifetime of the contract; however, the variability of the floating rate-LIBOR may positively or negatively impact on both Apple and HSBC. In this case, if the fixed rate exceeds the sum of LIBOR rate and the fixed spread, which means Apple needs to pay HSBC the amount of

$$\mathbf{\$1000 \times [fixed\ rate\ -\ (LIBOR + spread)],}$$

then this swap is a liability to Apple. Conversely, if Apple can earn from this contract, it therefore appears in the asset side of company's balance sheet. Thus, both parties in such a contract may encounter the CCR during the contract period. This means being bilateral.

[a]This index is scored by three prestigious credit rating agencies which are Moody's, Standard and Poor's as well as Fitch Ratings.

Finally, the values OTC derivatives are mark-to-market and thus privately set by all market participants. These values are not standardized like in the exchange market leading to a result that the value of an OTC derivative are much more volatile; hence, it also expands the total profit and loss volatility.

For example, assume that Apple has a large amount of OTC derivatives traded with HSBC bank. As an incident occurs, HSBC reports much weaker statistics than expected, which results in an increase in HSBC's credit spread[4] and therefore a decline in MTM value of OTC derivatives. Consequently, since the HSBC has a downgrade in credit rating, other institutions consider it more risky and hence they are prone to pay less with HSBC's contracts than previously. This means that Apple could have found more profitable OTC contracts on the market than those current contracts after the credit deterioration of HSBC. As the result, the total gain and loss of Apple is adversely affected. Also, this kind of impact on profit and loss seems highly undesirable and financial institutions will try to eliminate as much as possible. However, the unpredictable changes in the value of OTC contracts will only impact on banks' profit and loss during the active lifetime of the contract. When it expires or reaches the maturity, the possible *profit* & *loss* losses are offset. This is in case that no counterparty has not actually defaulted before.

3.3 Mitigating Counterparty Credit Risk

In the context of CCR, Netting and Collateral act as essential roles to mitigate this type of risk. The detail discussion for each type of concept is below.

3.3.1 Netting and ISDA Master Agreements

Definition

Netting is the process of allowing to offset the positive and negative value across the transactions in one netting set between two counterparties. In addition, "a netting set is a group of transactions with a single counterparty that are subject to a qualifying master netting agreement (MNA). A transaction not subject to a qualifying master netting agreement is considered to be its own netting set" [6] Netting enables firm to reduce the payment risk, counterparty risk towards its counterparty, especially when they involve in multiple contracts. Guidelines for netting were first introduced in

[4]The difference in yield between a risk free rate (often Government's bond yield) and a debt security of firm with the same maturity but of lesser quality.

Basel II.

Example: Netting

Assume two financial Firm A and Firm B enter into two interest rate swap agreements. At the settlement date, Firm A yeilds $100 mil from Firm B on the first contract. Conversly for the second contract, Firm B is due to gain $25 mil from Firm A. Without netting, firms will need to conduct discrete two discrete settlements and this may leads to settlement risk and operational workload[a].With netting, the payments would be netted and Firm B would simply give $75 mil to Firm A (as shown in **Figure 3.5**).

[a]This happens when in real case there are various transactions; not just only one like in the example.

(a) No netting effect. (b) Billateral netting.

Figure 3.5

Example of netting effect.

Firms could not privately negotiate the netting terms and so an establishment of International Swaps and Derivatives Association (ISDA) is necessary. The ISDA is a master service agreement for OTC derivatives practitioners and its function is to set up standard documents for OTC transactions. Today, most of financial firms enter into the ISDA master agreement published by the Association for their OTC trading. The ISDA Master Agreement contains legal terms and conditions, which cover many aspects of mitigating the counterparty risk such as netting, collateral, definitions of default. The master agreement is flexible and negotiable; however, once the contract is signed, then all the terms in the contract will automatically execute to all future transactions without any updates or modification. The ISDA master agreement facilitates counterparty risk management by allowing to combine all the referenced transactions into a single net obligation [4].

The Impact of Netting on Exposure

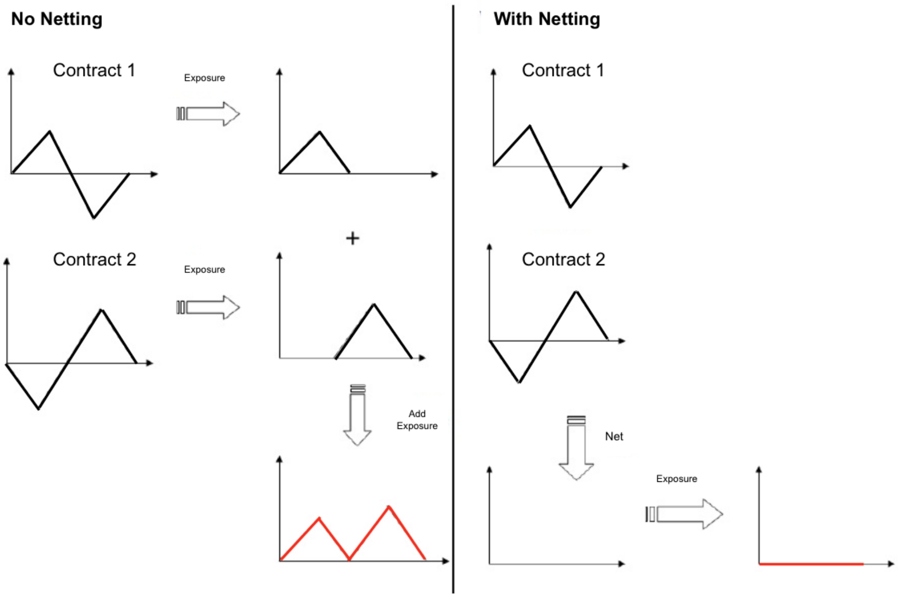


Figure 3.6

Illustration of with and without netting effect on exposure of 2 contracts.

Let consider a netting set consisting of N trades. If no netting is in place, the exposure would be equal to the sum of each trade's exposure in the netting set [8]:

$$E(t) = \sum_{i=1}^{n} \max(V_i(t,T), 0). \tag{3.3.1}$$

On the other hand, the exposure of the netting is determined by [8]:

$$E(t) = \max\left(\sum_{i=1}^{n} V_i(t,T), 0\right). \tag{3.3.2}$$

Mathematically, the effect of the netting is observed from the inequality:

$$\max\left(\sum_{i=1}^{n} V_i(t,T), 0\right) \leq \sum_{i=1}^{n} \max(V_i(t,T), 0), \tag{3.3.3}$$

where LHS is portfolio with netting effect and RHS is the one without netting effect.

3.3.2 Collateral and Credit Support Annex (CSA)

Definition

Collateral is another tool that helps firms to reduce the counterparty risk. The collateral could be cash or non-cash collateral (e.g. government securities), which is considered high liquid asset.

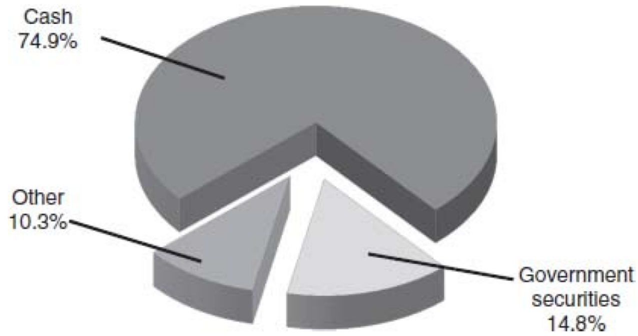


Figure 3.7

Breakdown of the categories of collateral.

Source: ISDA (2014).

In the context of derivative transactions, collaterlisation is the act that one or both counterparties are required to pledge some amount of assets as a resource (called collateral) to offset the adverse position of the underlying asset or an event of counterparty's default. In case of a counterparty defaults, surviving party will collect collateral to offset losses that might occur. In general, collateral contributes to a decrease in the exposure[5] and hence the CCR for trades towards a specific counterparty.

[5] In some rare cases, over-collateralisation could lead to an increase in exposure.

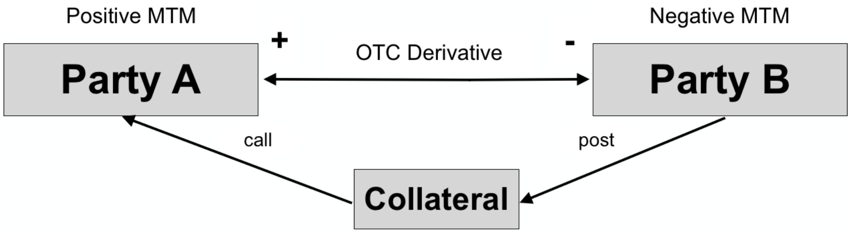


Figure 3.8

Party A will call for collateral from Party B if the MTM value of the contract reaches a threshold amount.

For the OTC derivatives contract, there is no obligation for either party to post collateral. Under the ISDA Master Agreement; however, firms could extend the ISDA contract with a Credit Support Annex (CSA)[6] that activates all terms relating to the use of collateral for any derivatives trades between two counterparties. The Annex covers different aspects such as: [9]

- Amount of collateral that will be posted or called;
- Time point of transferring collateral;
- Threshold amount[7];
- Minimum transfer amount[8] and rounding;
- Haircuts[9] applied to collateral categories;
- Triggers lead to a change in collateral conditions (e.g.deterioration of financial conditions that may leads to post more collateral...).

Furthermore, CSA agreement are classified into two types: one-way (unilateral) CSA and two-way (billateral) CSA. One-way collateral means that only one party can call

[6] An optional part out of 4 in an ISDA MAster Agreement

[7] The amount if MTM value < threshold, then no collateral can be called (under-collateralisation).

[8] The smallest amount that must be transferred.

[9] Haircut refers to a percentage of reduction when selling a collateral asset at the market price. The haircut of collateral depends on the volatility of the market price and liquidation of the asset.

and collect collateral under certain circumstances. This happens since only one party bears all the risk within the transaction. This type of single CSA is not common to derivative transactions, but usual for loans. Conversely, a two-way CSA is the most typical for derivative contracts, where both parties agree to post collateral based on the specific terms in CSA agreement. The purpose of this agreement is to reduce the exposure for surviving party and therfore mitigate the counterparty risk.

The impact of collateral on exposure

An influence of collateral on exposure can be expressed as [9]:

$$\text{Exposure} = \max(MTM - C, 0), \tag{3.3.4}$$

where C represents the value of collateral against the portfolio.
In general, there are three cases:

- C = 0: no collateral has been posted or received;
- C >0: collateral has been received; or
- C <0: collateral has been posted.

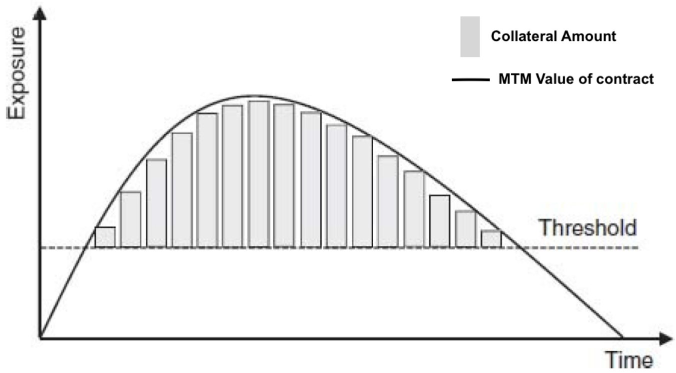


Figure 3.9

Illustration of collateral call based on MTM positions.

Chapter 4

Current Exposure Method

4.1 Overview

The CEM (originating from Basel I Accord 1988) is described details in the section VII, Annex IV of the Basel II Accord. So far, most of banks has been using it to compute the EAD. Along with SM (introduced lately in Basel II Accord), the CEM is publicly prescribed formula and costs not much money for banks that have not acquired approval for applying the internal method. Moreover, CEM has been updated throughout the years to adapt to new market conditions, especially for the term future exposure. However, its drawback is still lacking of the risk-sensitivity across some aspects such as the remaining maturity and MTM of the portfolio. In addition, the CEM method is considered to be replaced by the Standardized Approach for CCR (SA-CCR) in 2017, but it is a work for the future so the scope of the thesis will not cover this advanced method.

4.2 Methodology

The EAD under CEM is the sum of two components: Current Exposure (CE) and Potential Future Exposure (PFE). The CE is quite easy to obtain while the PFE is much more complicated since it represents the potential exposure that might occur during the remaining maturity. The formula for EAD (BCBS, 2006) under this method is given below:

$$EAD = CE + PFE, \tag{4.2.1}$$

where:

- **Current Exposure (CE):** the current market-to-market value of the contract. For a party, it equals the MTM of the portfolio if our firm have positive position in the contract or zero if otherwise. Therefore, CE = max(MTM;0) [9]. The detail method for calculation the MTM of the interest rate swap contract will be described in the **Section 6.2**.

- **PFE:** the estimated amount of the increased future exposure due to market movements of underlying asset over the remaining life of the contract. The PFE then depends on the remaining maturity and the underlying asset type (BCBS,2006) (see **Table 4.1**).

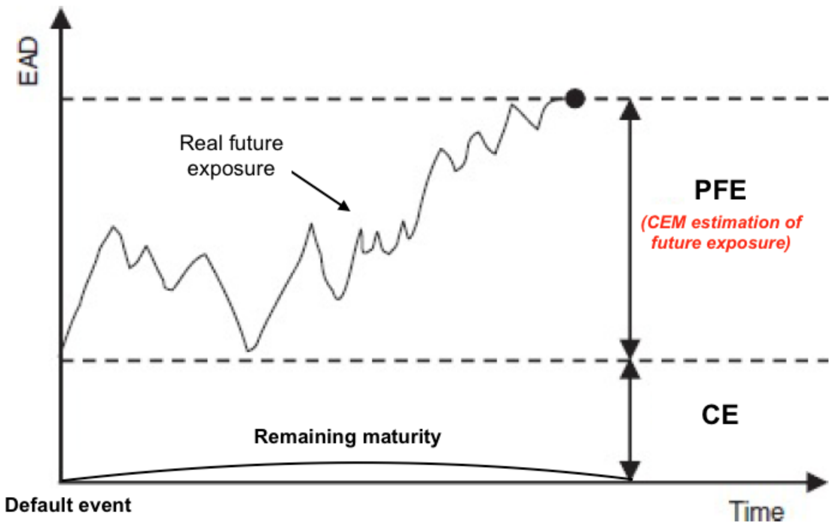


Figure 4.1

Illustration of determining the EAD via CE and PFE under CEM.

The PFE at single trade is computed by the product of the notional value of the contract and a regulatory fixed-rate named the Credit Conversion Factor (CCF) (see **Table 4.1**) [12].

Table 4.1

CCF Factors for CEM

Remaining	Interest rate	FX & Gold	Equities	Precious metal	Other commodity
<1 year	0%	1.0%	6.0%	7.0%	10%
1-5 year(s)	0.5%	5.0%	8.0%	7/0%	12.0%
>5 years	1.5%	7.5%	10%	8.0%	15%

Mathematically,

$$PFE(\text{without netting}) = \text{Notional Value} \times CCF. \quad (4.2.2)$$

4.3 Netting and Collateral under CEM

4.3.1 Netting Agreement

The Current Exposure Method recognises a netting effect but does so in quite simple way. According to a legally enforceable bilateral netting agreement, the CE is possible to fully net transactions. This is trivial as like an example in the **Figure 3.6** and the current netting exposure with a single counterparty is determined by the net portfolio exposure, that is, $CE_{netting} = \max\left(\sum_{i=1}^{n} MTM_i, 0\right)$ [9].
The PFE for a netting set is then given by [9]:

$$PFE(\text{with netting}) = \sum_{i=1}^{n} PFE_i \times (0.4 + 0.6 \times NGR), \quad (4.3.3)$$

where PFE_i is the estimated future exposure for the contract i and NGR- the net gross ratio is a percentage that reflects the efficiency of netting on the current exposure[1]. In term of PFE, a complete netting of positive and negative future exposures is not allowed (no perfect netting on PFEs). A floor of 0.4 of total PFEs is maintained during the process of netting. Therefore, the PFE of a netting set should be kept at least at 40% of total PFE. The remaining $(0.6 \times NGR)$ can be seen as a proxy for

[1] An NGR = 0 means perfect netting and an NGR = 1 reflects no netting benefit on current exposure.

the current impact of netting on PFE. This amount depends on the "market value structure" of the bilateral derivative portfolio. The NGR is computed as the ratio of the current netting exposure to the sum of each current exposure of all transactions in the netting set[2] [9]:

$$NGR = \frac{CE_{\text{netting}}}{\sum_{i=1}^{n} \max(MTM_i, 0)}. \tag{4.3.4}$$

4.3.2 Collateral Agreement

In presence of a collateral agreement with counterparty, the EAD will be calculated as [10]:

$$EAD = \max\left(\sum_{i=1}^{n} MTM_i, 0\right) + PFE - \text{Collateral}. \tag{4.3.5}$$

Collateral deduction in the CEM method has been allowed since the Basel II. This means that the current exposure of a netting set can be reduced by the received amount of collateral. Especially, the effect of collateral only recognises in the CE but not the PFE. In the presence of non-cash collateral, the value of the collateral is discounted subject to hair-cut market value (see **Section 3.3.2**). In the collateral agreements, counterparties periodically mark to market their contract positions and if an contract exposure exceeds the pre-agreed thresholds, an disadvantage firm needs to post more collateral by transferring the ownership of those assets to compensate for the downgrade in interest rate positions.

[2]More details can be found in Annex IV of the Basel capital framework, Part 5, *Basel II: International Convergence of Capital Measurement and Capital Standards: A Revised Framework* (available at `www.bis.org/publ/bcbs128d.pdf`).

Chapter 5

The Internal Model Method

5.1 Overview

The internal method model is the most advanced method used by most sophisticated banks to compute the EAD. In addition, banks have to gain regulatory approval to apply it. IMM has been the most risk-sensitive approach for EAD so far but very costly and difficult to implement. Under the IMM, EAD are computed by multiplying the α with an effective expected potential exposure (EEPE). These two terms are discussed thoroughly in the next part **Methodology**. Banks with IMM application generally spend less amount of capital saving than under the basic CEM approach. However, the trade-off between a full-scale model and the cost often take banks into a careful consideration to select between the CEM and IMM. To run the IMM model, financial institutions must have at least three years of historical data[1] to generate future exposure scenario by Monte Carlo simulation. Due to the scarcity of data, the practical calculation of EAD under IMM through programming model will not be included in this thesis.

In general, the merits of IMM are:

- Precise model for all underlying risk parameters and the reliable estimation of future exposure to compute EAD;
- Full netting effect for current exposure as well as potential exposure ; and

[1] One-year data must be tested at stressed scenarios.

- Collateral benefit, also covering the estimation of future received collateral by simulating specific future scenarios[2].

5.2 Methodology

The EAD under IMM is also calculated at a netting set level. The formula for EAD is given as [9]:

$$EAD = \alpha \times EEPE, \tag{5.2.1}$$

- α

  The alpha factor is a mean of conditioning the estimated expected positive exposure (EPE) under adverse market circumstances. Moreover, it helps to adjust the wrong way risks (WWRs) erros and other internal issues.

  These errors includes [3]: "**(1)** correlations of exposures across counterparties exposed to common risk factors; **(2)** the potential lack of granularity across a firm's counterparty exposures; and **(3)** model estimation and numrical errors."

  In Basel II, a regulatory prescribed value for α is 1.4. However, banks are allowed to use their own models[3] for optimizing the value α, which is set to the minimum floor of 1.1 or 1.2 [17]. For a smaller α multiplier, banks could save a moderate regulatory CCR capital.

- Effective Expected Positive Exposure (EEPE)

  It was first introduced in the Basel Accord 2005 for the regulatory capital purposes. To determine the EEPE, banks must generate an exposure profile via Monte Carlo simulation. The profile consists of four essential metric exposures, which are now discussed in detail.

[2] Firms need a regulatory approval for the simulating collateral model to obtain full risk mitigation.

[3] These models should be fully assessed and agreed by the Basel Accord; hence in practice, banks often choose the regulatory α of 1.4 for the convenience.

EE - Expected exposure

This figure is an average of all estimated exposure values at specific time point towards a counterparty.

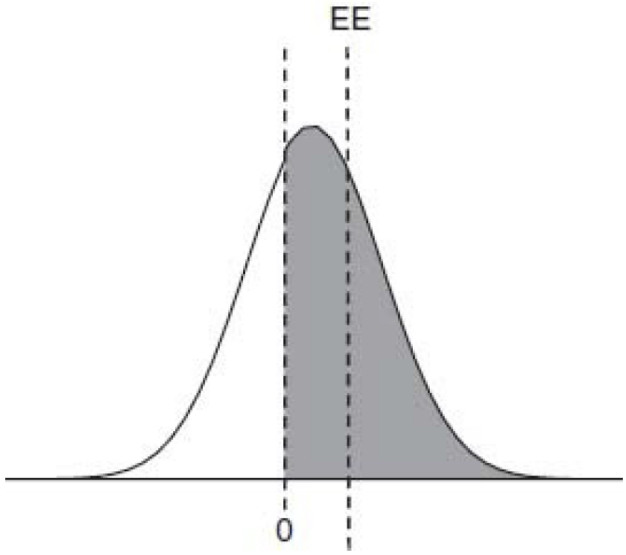


Figure 5.1

Illustration of EE by right-skewed distribution. Note that only shaded area gives rise to (positive) exposures and other are has no contribution (although these values contribute to the probability distribution).

Mathematically, let denote $E_i(t)$ as i^{th} simulated exposure value at time t. Then, the EE towards the counterparty at time t is [6]:

$$EE(t) = E\Big[E_i(t)\Big], \tag{5.2.2}$$

EPE - Expected positive exposure

The EPE is the weighted average[4] of all the EEs in a specific time interval, denoted H.

[4]The weights is determined by dividing each distance between time points by the total time interval.

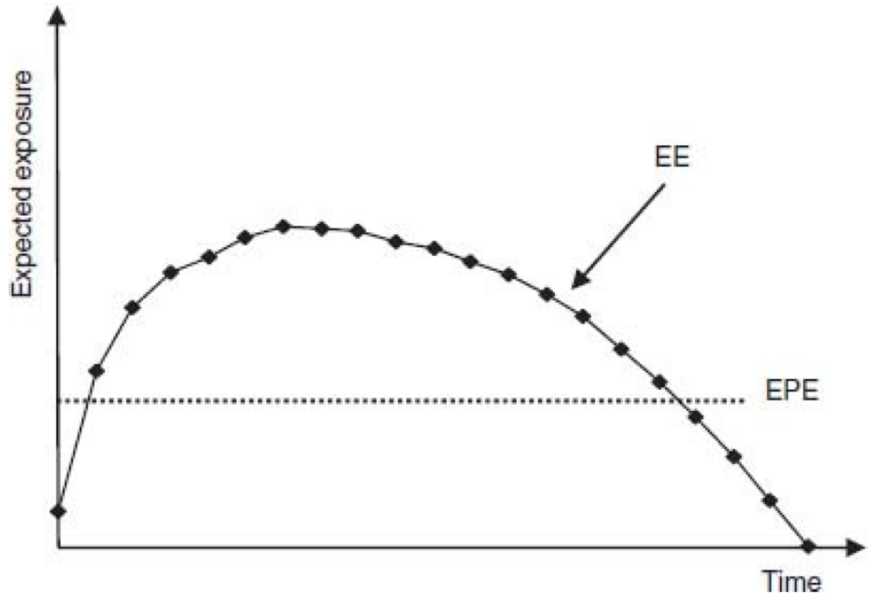


Figure 5.2

Illustration of EPE, which is the weighted average of the EEs.

Mathematically, the formula for EPE is [6]:

$$EPE = \frac{1}{H} \sum_{t_i < H} EE(t_i) \Delta t_i, \tag{5.2.3}$$

In addition, if EE points are equally spaced, then the EPE is basically the average.

$$EPE = \frac{\sum_{i=1}^{n} EE(t_i)}{n-1}. \tag{5.2.4}$$

EEE - Effective expected exposure

The EEE is a non-decreasing version of the EE profile. The EEE at a specific time is [6]:

$$EEE(t_i) = \max\Big\{EEE(t_{i-1}), EE(t_i)\Big\}. \tag{5.2.5}$$

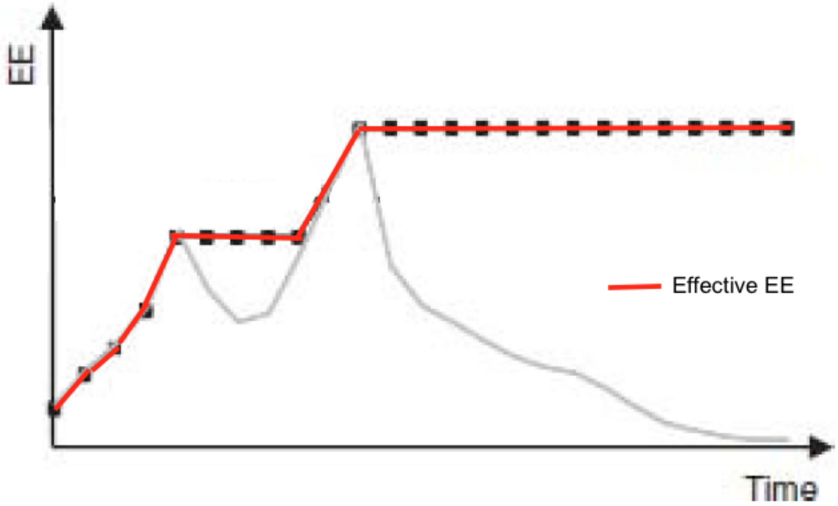


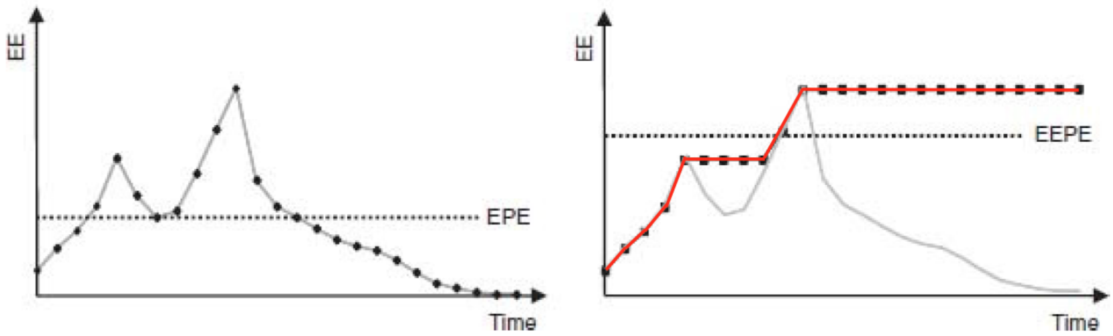
Figure 5.3

Illustration of Effective EE.

EEPE - Effective expected positive exposure

The last term in the exposure profile is EEPE. As mentioned above, EEPE has been used for the regulatory capital purposes since Basel 2005. It also replaces the EPE in the EAD calculation under IMM since the EPE may underestimate very large exposures that exist in only small time[5]. In gerneral, EEPE is usually higher than the EPE.

[5]The time-weighted average of these large exposures is very small and compensated by the decreasing exposures that represent for a long time.



(a) EPE. (b) Effective EPE.

Figure 5.4

Illustration of the difference between EPE and EEPE.

Similar to the EPE, the EEPE is defined as the time-weighted average of the EEE profile within a specific time interval (H) [6]:

$$EEPE = \frac{1}{H} \sum_{t_i < H}^{n} EEE(t_i) \Delta t_k. \tag{5.2.6}$$

Chapter 6

EAD Calculation for OTC IRS Contracts Portfolio

6.1 Calculation Method and Purposes

In this thesis, I only use the current exposure method to calculate the EAD of the interest rate swap contracts portfolio. The detail information and illustration of the portfolio will be presented in the next **Section 6.2**. The IMM model, as mentioned above, demands the simulation of the future yield curves (e.g. using Hull-White model) to derive the exposure profile. These simulations require complex data, which is extracted from private banks' account[1]; hence, the access for such type of data is very hard to overcome.

Furthermore, in most immature financial markets where Basel implementation is very basic and fundamental (especially currently in Vietnam there are only 10 largest banks have been piloted to implement the Basel II), the practice for advanced models in lately Basel II & III such as IMM is impossible. For this reason, CEM seems to be more suitable in these emerging markets as it is easy-to-use and just requires a simple data for EAD calculation.

[1] Only the minority of large-scale banks in the world could collect enough data for IMM usage due to the cost and complexity.

The illustration and guidance of EAD approach under CEM are displayed thoroughly in Microsoft Excel 2016. The aim is to help users get acquainted with some components in the interest rate swap portfolio to compute the MTM value and also the exposures. It also includes the technique to acquire the zero yield-curve for swap calculation. In addition, an automatic EAD calculator under CEM is provided for practicing and is executed in R version 3.4.0 (2017-04-21). It is fast and convenient for the users, even for ones who do not expertise in exposure at default as well as Basel knowledge. Users just need to input some simple parameters of the swap contracts and current market Libor-based rates (which are very easy to obtain from the Internet and also have the link to download in Excel), then the calculator will automatically returns the amount of EAD for the IRS contracts portfolio.

With the calculator, the sensitivity of EAD towards netting and collateral effects are tested under some scenarios. This will be discussed in a **Section 6.6**.

6.2 Valuation of Interest Rate Swap [7]

6.2.1 Introduction

According to a recent survey of Bank of International Settlements (BIS), the outstanding amounts of the interest rate swap contracts surpassed $357 trillion or $8.1 trillion in gross market value. The size and increasing trading volume of this type of OTC derivative products attest to their widespread acceptance as essential risk hedging and management tools for financial institutions, government entities and especially banking systems.

An IRS contract is a bilateral agreement between two parties to exchange a interest rate cash flows on specified maturity and over a certain period of payment. The cash flows could be fixed or floating that equals to a constant contract's notional amount multiples with a referenced rate.

There are various types of IRS contracts; however, the so far most popular one, and will be discussed mainly in this thesis, is the plain-vanilla "fixed for floating" interest rate swap. In a plain-vanilla swap, one party makes a fixed payments corresponding to an advance fixed rate of interest (Payer), while the other pays a floating rate based on a Libor rate[2] (Receiver). These rates are charged on a notional amount or principal amount[3].

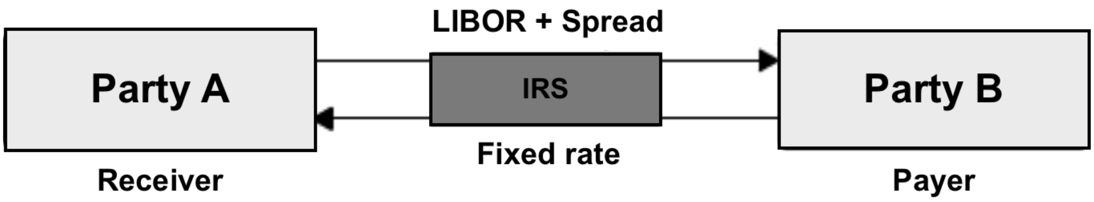


Figure 6.1
Illustration of two counterparties in a IRS agreement. Party A receives the fixed rate and hence plays as a receiver, while party B is a payer of the swap. The LIBOR rate is a reference floating rate and an additional spread usually given in basis points (bps), with 1bp = 0.01% .

6.2.2 A Framework for Valuation

Let B^{fix} denotes the value of all fixed cash flows (CFs) in the IRS agreement, while B^{flt} denotes the value of the floating CFs. Then:

$$B^{\text{fix}} = \sum_{t=1}^{n} \frac{\bar{C}}{(1+{}_0R_t)^t} + \frac{N}{(1+{}_0R_n)^n} \tag{6.2.1}$$

$$B^{\text{flt}} = \sum_{t=1}^{n} \frac{\tilde{C}}{(1+{}_0R_t)^t} + \frac{N}{(1+{}_0R_n)^n}, \tag{6.2.2}$$

where:

- N: the face or notional amount of the contract.

[2]This is a reference interest rate listed on the market exchange and very fluctuating.
[3]This amount is never exchanged and remains constant during the life of a contract.

- $\bar{C}$: the fixed CFs payment each period.
- $\tilde{C}$: the floating CFs payment each period.
- ${}_0R_t$: the pure discount rate of a bond having a maturity t.

Note that all CFs are discounted by a unique zero coupon rate corresponding to the specific timing of the CF.

The value (V) of swap corresponding to a Receiver ('receive fixed, pay floating') is:

$$V = B^{\text{fix}} - B^{\text{flt}}. \tag{6.2.3}$$

Similarly, the value corresponding to a Payer ('pay fixed, receive floating') is:

$$V = B^{\text{flt}} - B^{\text{fix}}. \tag{6.2.4}$$

At each time during the contract, this value is also called the mark-to-market value of the swap, which depends on the variability of the floating rates at each period of valuation. The positive value means that our party exposes to the loss of this amount in case of the counterpaty defaults; while negative value means that our party exposes to the loss amount of 0. Hence, the current exposure = max(MTM,0)

6.2.3 A Numerical Example

Consider an one-year (360 days) plain-vanilla IRS contract having semi-annual payments (two 180-day intervals) and notional principal of \$1. The Libor interest rates is selected as a reference rate for determining the floating payments. The settlement of CFs will occur at two days (180^{th} and 360^{th} days of the period). Assume that ${}_0\text{L}_{180} = 6.00\%$ and ${}_0\text{L}_{360} = 7.00\%$ (Libor rate of 6 months and 1 year respectively). The fixed rate is set at 6.86% and the payer therefore make a fixed payment each period of $\bar{C} = (\$1 * \dfrac{6.86\%}{2})$= \$0.0343 per \$1 of notional value. Then, the value for fixed CFs will be:

$$B^{\text{fix}} = \frac{\bar{C}}{(1 + 0.06 * \frac{180}{360})} + \frac{\bar{C} + 1}{(1 + 0.07 * \frac{180}{360})} = \$1.00. \tag{6.2.5}$$

For the receiver, they have to follow the standard convention that floating payments are based on Libor rates observed at each start date of the period. In this case, only the first floating payment is known in advance since it is set on the swap initiation date and based on the 6-month LIBOR rate on that day: $\tilde{C}_1 = \$1 * 6.00\% * 180/360$=\$0.03. The value of the floating CFs will be:

$$B^{\text{flt}} = \frac{\tilde{C}_1 + 1}{(1 + 0.06 * \frac{180}{360})} = \$1.00. \tag{6.2.6}$$

Thus, the value of swap at initiation will be (for both Payer and Receiver):

$$V = B^{\text{fix}} - B^{\text{flt}} = 0. \tag{6.2.7}$$

The value of the swap equals to 0 at the initiation as it needs to be fair for both parties. However, this value may change during a life of contract due to changes in factors that affects the value of the underlying asset. Plain vanilla swaps, like most derivative instruments, have zero value at initiation. Like other derivatives, IRS contracts are zero-sum instruments, so any positive value increase to one party is a loss to the other.

Next, I will make a discussion on how to value a swap at the following times from the origination. Two factors could lead the swap to take on positive or negative value are the passage of time and changing market interest rates. Within the above contract, assume that 10 days has elapsed while market rate of interest (Libor) has increased. This means that the two remaining settlement dates are now 170 and 350 respectively. Assume that ${}_0\mathrm{L}_{170} = 6.50\%$ and ${}_0\mathrm{L}_{350} = 7.50\%$.

First, consider the floating position. Since only 10 days have passed, the first floating cash flow of \$0.03 to be paid at the first settlement is still effective. Moreover, the new floating payable amount for the second settlement will be reconsidered based on the 6-month LIBOR rate effective at the end of first settlement. The value of B^{flt} is now changing to:

$$B^{\text{flt}} = \frac{\$0.03 + \$1}{(1 + 0.065 * \frac{170}{360})} = \$0.99933. \tag{6.2.8}$$

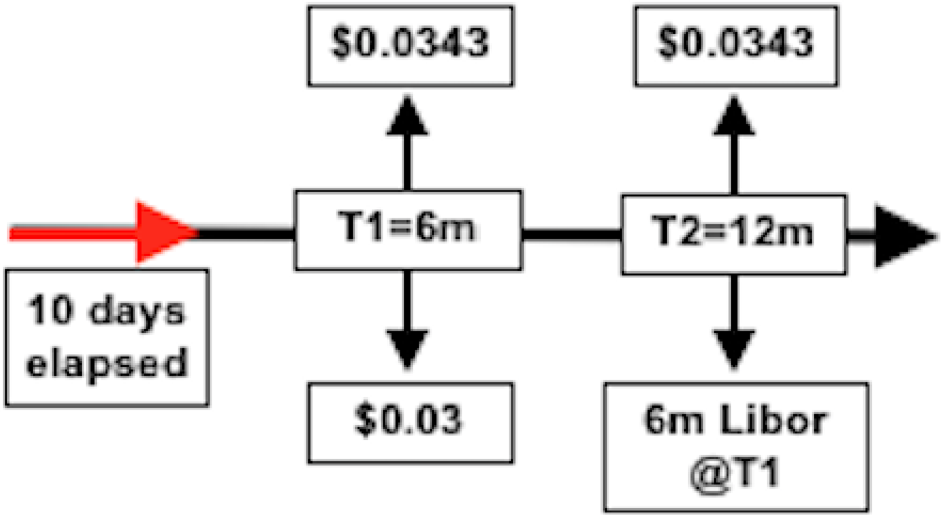


Figure 6.2

Illustration of the structure of payments for the IRS contract in an example .

For the fixed position, the CFs still consists of two fixed payments of \$0.0343 along with the notional amount. The only change is the discount factor. Hence, the value of B^{fix} is:

$$B^{\text{fix}} = \frac{\$0.0343}{(1 + 0.065 * \frac{170}{360})} + \$0.0343{+}\$1(1 + 0.075 * \frac{350}{360}) = \$0.99729. \tag{6.2.9}$$

Finally, the value of the swap (at the tenth date of the contract) is equal to:

$$V = B^{\text{flt}} - B^{\text{fix}} = \$0.00204. \tag{6.2.10}$$

This amount of value is for the Payer of the contract. For the Receiver (receive fixed rate), a swap would have a value of -\$0.00204. The difference of \$0.00204 also reflects the profit/loss on the swap over the 10 day interval due to the passage of time and the increase in interest rates.

In my calculation in Excel and Matlab, the same method of determining the value or (more specifically) the MTM value of the swap contracts is executed.

6.3 The Zero (Discount) Curve

The zero discount curve or zero curve is the line consisting of discount rates of corresponding maturity of each payment date. These rates are usually drawn from a Libor-based, which could be US dollar (USD), Euro (EUR), pound sterling (GBP), Japanese yen (JPY) and Swiss franc (CHF) and available to seven different maturities: overnight, 1 week, and 1, 2, 3, 6 and 12 months[4].

There are three steps to construct the zero curve for valuation of IRS contracts. They are:

1. Choose reference market interest rates;
2. Make convexity adjustments; and
3. Construct the zero discount curve

6.3.1 Market Data

For rates at the short end of the curve, I select the USD Libor spot rates as the reference for short-term interest rate. The reason is that USD Libor rates are the world's widely-used benchmark of short-term interest rate. For the middle and longer term portions of the zero curve, the maturity of Libor rate could not cover the time interval since the longest maturity of the spot Libor rates is only 12 months. Hence, I need to collect more other rates to complete a Libor-based discount rate; and one of them is Eurodollar futures.

Eurodollar futures, quoted on the Chicago Mercantile Exchange, are one of the most liquid and heavily traded financial instruments due to their role in pricing and hedging IRS. The price of Eurodollar futures reflects the interest rate offered on USD denominated deposits held in banks outside the United States. More specifically, the maturity of the futures only last about 3 months and hence their prices also reflects the market gauge of the 3-month USD Libor interest rate anticipated on the

[4]For example, a USD Libor 3-month.

settlement date of the contract. Quotes on the Eurodollar futures are sufficient to construct maturities that extend out 5 years. To find the implied future rates from the quoted price, we just need to subtract the observed price from 100. For instance, an Eurodollar future quotes at 90.00 is associated with the rate of 10%[5].

The market data I use to construct the zero curve for IRS portfolio calculation is illustrated in **Table 6.1**. A set of sample spot Libor rates and Eurodollar futures prices observed on April 27, 2017. 1-, 3-, 6-month USD Libor spot rates are given[6]. In addition, Eurodollar futures prices and corresponding implied futures rates contracts[7], are selected to estimate the rates for a middle and long maturity of payment date. The Eurodollar futures data begins with the Sep 2017 contract and extends to the Mar 2022 contract to fit the longest maturity of the 5-year swap contracts in my portfolio.

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[5]The standard notional amount of the Eurodollar futures is \$1 mil USD. Hence, 1 basis point changes in the implied rate making a \$1 mil*0.0001*90/360=\$25 opposite change in contract value.

[6]Source: `http://www.global-rates.com/interest-rates/libor/american-dollar/american-dollar.aspx`.

[7]Source: `http://www.cmegroup.com/trading/interest-rates/stir/eurodollar.html`.

Table 6.1

Raw market data for the Zero Curve Construction (April 27, 2017)

(a) Libor Spot Rate Information

Term	Maturity	Days	Rate (%)
1-month	27-May-17	30	0.995
3-month	27-Jul-17	91	1.169
6-month	27-Oct-17	183	1.430

(b) Eurodollar Futures Information

Contract	Price	Futures Rate (%)	Start Date	End Date
Sep 2017	98.600	1.400	27-Sep-17	27-Dec-17
Dec 2017	98.510	1.490	27-Dec-17	27-Mar-18
Mar 2018	98.425	1.575	27-Mar-18	27-Jun-18
Jun 2018	98.330	1.670	27-Jun-18	27-Sep-18
Sep 2018	98.240	1.760	27-Sep-18	27-Dec-18
Dec 2018	98.140	1.860	27-Dec-18	27-Mar-19
Mar 2019	98.080	1.920	27-Mar-19	27-Jun-19
Jun 2019	98.020	1.980	27-Jun-19	27-Sep-19
Sep 2019	97.965	2.035	27-Sep-19	27-Dec-19
Dec 2019	97.885	2.115	27-Dec-19	27-Mar-20
Mar 2020	97.845	2.155	27-Mar-20	27-Jun-20
Jun 2020	97.795	2.205	27-Jun-20	27-Sep-20
Sep 2020	97.750	2.250	27-Sep-20	27-Dec-20
Dec 2020	97.690	2.310	27-Dec-20	27-Mar-21
Mar 2021	97.650	2.350	27-Mar-21	27-Jun-21
Jun 2021	97.610	2.390	27-Jun-21	27-Sep-21
Sep 2021	97.565	2.435	27-Sep-21	27-Dec-21
Dec 2021	97.515	2.485	27-Dec-21	27-Mar-22
Mar 2022	97.485	2.515	27-Mar-22	27-Jun-22

6.3.2 Make Convexity Adjustments to Implied Eurodollar Futures Rates

One of the features of the futures market that is the daily re-settlement[8] makes the implied futures rate seems to be an upward biased of its actual one. A reason for the upward biased of the implied futures rates can be illustrated below.
Assume that a Eurodollar futures contract quotes at 90.00 (corresponding implied futures rate of 10%). In a context of long position, if the price increases 5 points to 95.00, which means implied futures rate reduces 500 bps from 10% to 5%, then, the following daily resettlement, he will show a profit of \$25 $\times$ 500 bps=\$12,500 (1 bp decrease in the implied rate corresponds to a \$25 increase in contract value). These profit could be invested elsewhere to earn 5%. For short position, the account will show a loss of \$12,500, which is financed at 5%. On the other hand, consider the case that the price decreases 5 points to 85.00, which means implied futures rate increase 500 bps from 10% to 15%. The short position now earns a profit of \$12,5000, which could be invested at 15%. Conversely, the long position incurs a loss of \$12,500, which is financed at 15%.

Based on the probability theory, the event of positive or negative price changes is equally likely. So the above circumstance is obviously unfair for the long position since with the same chance of win or lose, he would always invest his profit at a relatively lower rate and finance his loss at a relatively higher rate compared to the short position. The long criticizes this partiality and demands for a compensation to encourage them to trade. Then, the short agree to a lower equilibrium price than it would be otherwise there is no daily re-settlement. The result is that the implied futures rate becomes the upward biased compared to its actual one.

[8] "The amount of money that has to be paid at the end of each trading day by a futures trader in order to make an additional margin payment required by the price change of the futures contracts. The accounts of futures traders are marked-to-the market at the end of each trading day, meaning that current prices are applied to calculate the brokerage account balances that traders have" [18].

A "convexity adjustment" technique is therefore employed to correct the bias of the implied futures rate. The convexity adjustment value equals to:

$$\text{Convexity Adjustment} = \frac{1}{2} \times \sigma^2 \times \frac{T_1}{360} \times \frac{T_2}{360}, \tag{6.3.11}$$

where:

- σ: the annualized standard deviation of the change in the short-term interest rate. In normal financial condition, σ often appears to be 1%.
- T_1: the time (year) from the starting date of the calculation (our case is April 27, 2017) to the starting date of Eurodollar futures contract.
- T_2: the time (year) from the starting date of the calculation to the maturity date of Eurodollar futures contract.

Finally, we need to subtract the convexity adjustment value from the implied futures rate to acquire the actual rate.

Table 6.2

Processed market data for the Zero Curve Construction (April 27, 2017)

(a) Libor Spot Rate Information

Term	Maturity	Days	Rate (%)
1-month	27-May-17	30	0.995
3-month	27-Jul-17	91	1.169
6-month	27-Oct-17	183	1.430

(b) Actual rates derived from the implied Eurodollar futures rates

Contract	Price	Start Date	Days (T_1)	End Date	Days (T_2)	Future Rate(%)	Actual Rate(%)
Sep 2017	98.600	27-Sep-17	153	27-Dec-17	244	1.400	1.399
Dec 2017	98.510	27-Dec-17	244	27-Mar-18	334	1.490	1.487
Mar 2018	98.425	27-Mar-18	334	27-Jun-18	426	1.575	1.570
Jun 2018	98.330	27-Jun-18	426	27-Sep-18	518	1.670	1.662
Sep 2018	98.240	27-Sep-18	518	27-Dec-18	609	1.760	1.748
Dec 2018	98.140	27-Dec-18	609	27-Mar-19	699	1.860	1.844
Mar 2019	98.080	27-Mar-19	699	27-Jun-19	791	1.920	1.899
Jun 2019	98.020	27-Jun-19	791	27-Sep-19	883	1.980	1.954
Sep 2019	98.965	27-Sep-19	883	27-Dec-19	974	2.035	2.003
Dec 2019	98.885	27-Dec-19	974	27-Mar-20	1065	2.115	2.076
Mar 2020	98.845	27-Mar-20	1065	27-Jun-20	1157	2.155	2.109
Jun 2020	98.795	27-Jun-20	1157	27-Sep-20	1249	2.205	2.151
Sep 2020	98.750	27-Sep-20	1249	27-Dec-20	1340	2.250	2.187
Dec 2020	98.690	27-Dec-20	1340	27-Mar-21	1430	2.310	2.238
Mar 2021	98.650	27-Mar-21	1430	27-Jun-21	1522	2.350	2.268
Jun 2021	98.610	27-Jun-21	1522	27-Sep-21	1614	2.390	2.298
Sep 2021	98.565	27-Sep-21	1614	27-Dec-21	1705	2.435	2.332
Dec 2021	98.515	27-Dec-21	1705	27-Mar-22	1795	2.485	2.370
Mar 2022	98.485	27-Mar-22	1795	27-Jun-22	1887	2.515	2.388

6.3.3 Construct the Zero Curve

One of the standard techniques to build the zero curve is a bootstrapping method which combines the short-term Libor spot rates with actual rates from Eurodollar futures to form a comprehensive Libor-based discount rate. The quotes of futures contracts' maturities could extend out 5 years, so we can use this technique to develop a Libor-based discounted curve of similar maturity.

The bootstrapping technique for the zero rate will be illustrated in an example below.

Example: BOOTSTRAPPING EXAMPLE

Consider one wants to construct a zero curve beginning from March 1 2017 to December 1 2017. A market data includes a 6-month Libor (last around 183 days) rate of 1.43% and a Sep 2017 futures contract (last around 91 days and mature on Dec 2017) of 1.399% (this is the rate after adjusting convexity). Let denote these two rates as ${}_0\mathrm{L}_{183}$ and ${}_{183}\mathrm{L}_{91}$ respectively. In order to complete the discount curve, he needs to calculate 9-month (or 274-day) Libor-based discount rate or ${}_0\mathrm{L}_{274}$. The ${}_0\mathrm{L}_{274}$ can be computed by linking the two given rates as follows:

$$\left(1 + {}_0L_{274} \times \frac{274}{360}\right) = \left(1 + {}_0L_{183} \times \frac{183}{360}\right) \times \left(1 + {}_{183}L_{91} \times \frac{91}{360}\right)$$
$$\left(1 + {}_0L_{274} \times \frac{274}{360}\right) = \left(1 + 0.0143 \times \frac{183}{360}\right) \times \left(1 + 0.01399 \times \frac{91}{360}\right)$$
$${}_0L_{274} = 0.01423 = 1.423\%.$$

Similarly, if he continues want to derive the 365-day Libor-based discount rate, he just need to link the 275-day rate just derived with the 91-day rate associated with the Dec 2017 futures contract as follows:

$$\left(1 + {}_0L_{365} \times \frac{365}{360}\right) = \left(1 + {}_0L_{274} \times \frac{274}{360}\right) \times \left(1 + {}_{274}L_{91} \times \frac{91}{360}\right)$$

.

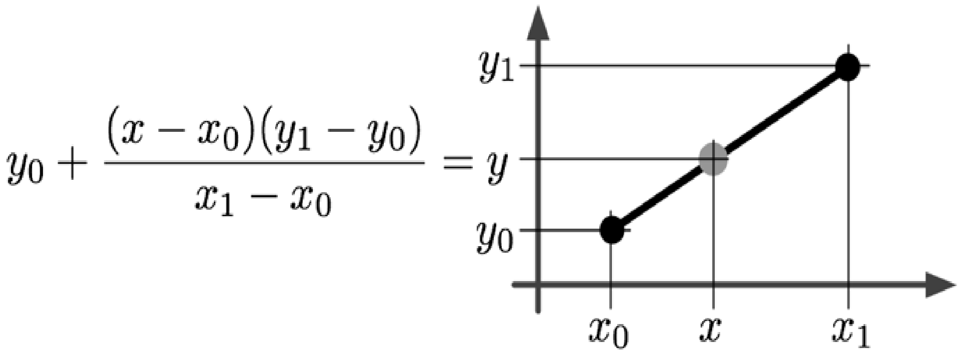

Figure 6.3

Illustration of the linear interpolation technique. In our calculation, y refers to the rate while x refers to the time interval (days).

However, the computed rates comprising the Libor-based have maturities corresponding to the futures maturity dates. These dates may not match the swap payment dates and hence we can not discount the payment CFs from these rates. To solve this problem, one can interpolate between the computed Libor-based rates to produce additional discount rates to fit in the zero curve that match the swap CFs dates. Let see an example below to illustrate the interpolation technique.

Example: **INTERPOLATION EXAMPLE**

Assume the stat date is March 1, 2017. The 1-month Libor spot rate will extend to 31 days to to April 1, 2017 while 3-month rate will extend to 92 days to June 1, 2017. However, what is needed is a spot rate extending 61 days to May 1, 2017. Assume that 1- and 3-month Libor rates are 1.00% and 2.00% respectively. Through linear interpolation, the 61-day rate can be estimated as:

$$
\begin{aligned}
{}_0L_{61} &= {}_0L_{31} + ({}_0L_{31} - {}_0L_{92}) \times \frac{61 - 31}{92 - 31} \\
{}_0L_{61} &= 1.00\% + (2.00\% - 1.00\%) \times \frac{61 - 31}{92 - 31} \\
{}_0L_{61} &= 1.91\%.
\end{aligned}
$$

Table 6.3

Libor-based discount rates for zero-curve after applying interpolation and bootstrapping technique.

Maturity (years)	Discounted Rate(%)
0.25	1.16956
0.50	1.43044
0.75	1.58933
1.00	1.57392
1.25	1.58345
1.50	1.60666
1.75	1.63764
2.00	1.67202
2.25	1.70633
2.50	1.74053
2.75	1.77485
3.00	1.80928
3.25	1.84217
3.50	1.87457
3.75	1.90642
4.00	1.93742
4.25	1.96777
4.50	1.99768
4.75	2.02726
5.00	2.05576

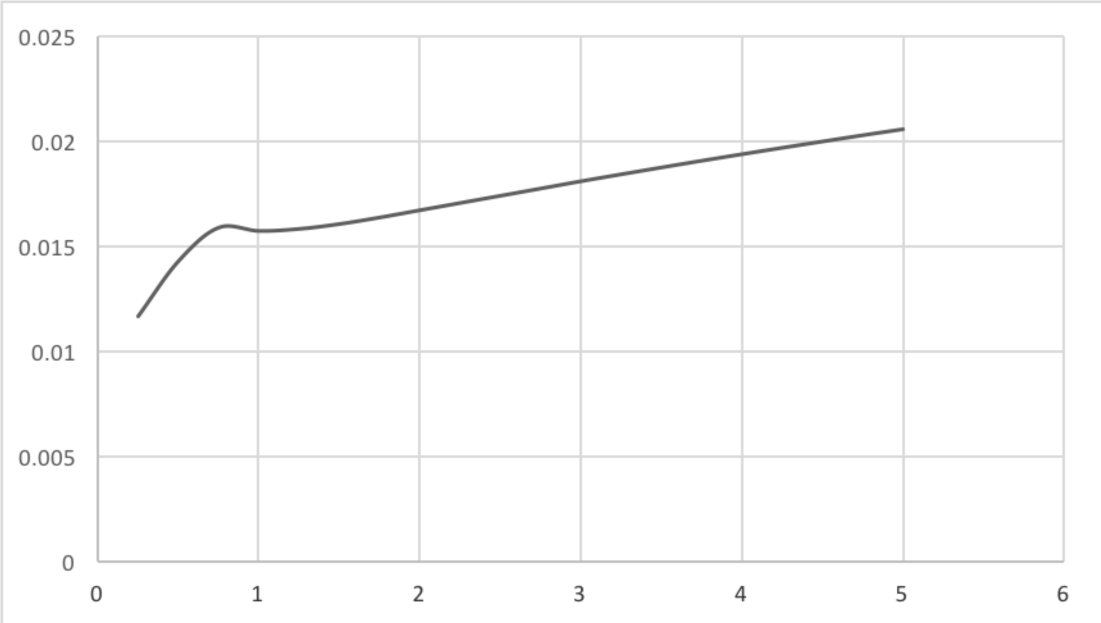

Figure 6.4

The final zero (discount) curve with Libor-based for the swap portfolio.

(Start Date: April 27, 2017)

6.4 Portfolio

A **Table 6.4** below illustrates the portfolio data for the EAD calculation. All the swaps start from April 27, 2017 and a swap's longest maturity is the 5-year swap ending at April 27, 2022. The "principal" is the notional amount of each contract in billion USD. "Type of swap" is a contract's maturity. "Payment period" is a frequency of settlement during the contract life. "Leg type" of 1 refers to a party "receive fixed, pay floating" and 0 means "pay fixed, receive floating". The fixed position will receive a predetermined fixed rate while the floating position will receive a relevant Libor rate plus a constant spread (in bps).

Table 6.4

Portfolio of IRS contracts for EAD calculation.

Counterparty	Contract ID	Principal ($ bil)	Type of swap	Payment Period	Start Date (T0)	First Payment Date (T1)	Maturity Date	Leg type	Leg rate receiving(%)	Leg rate paying(%)
A	1	1	2-year	quarter	4/27/17	7/27/17	4/27/18	1	1.58	LIBOR+10 basis
A	2	3.6	1-year	semi-annual	4/27/17	10/27/17	4/27/18	0	LIBOR+5 basis	1.39
A	3	4	2-year	semi-annual	4/27/17	10/27/17	4/27/19	0	LIBOR+5 basis	1.58
A	4	1.4	1-year	quarter	4/27/17	7/27/17	4/27/18	1	1.39	LIBOR+10 basis
A	5	4.2	5-year	annual	4/27/17	4/27/18	4/27/22	1	1.96	LIBOR+15 basis
B	6	2.5	1-year	semi-annual	4/27/17	10/27/17	4/27/18	1	1.39	LIBOR +7 basis
B	7	5	5-year	annual	4/27/17	4/27/18	4/27/22	0	LIBOR + 8 basis	1.96
B	8	6.3	3-year	annual	4/27/17	4/27/18	4/27/20	0	LIBOR +10 basis	1.72
C	9	5.5	5-year	annual	4/27/17	4/27/18	4/27/22	1	1.96	LIBOR + 5 basis
C	10	7	3-year	semi-annual	4/27/17	10/27/17	4/27/20	1	1.72	LIBOR +5 basis

The portfolio consists of three counterparties with their corresponding IRS contracts. The data of IRS contracts are generated based on the real US market swap value at the date April 27, 2017[9]. I choose the US data since in our country-Vietnam, the derivative market has not been established yet. Only few financial institutions, especially international banks may trade similar products or have a trading database of derivatives with foreign counterparties; however, an approach to their database seems to be impossible. Moreover, many emerging markets in our region so far such as Thailand, Malaysia have been referencing to many characteristics of the standardized derivative contracts in the US (e.g. using the same USD Libor rate as reference floating rate, or same netting and collateral regulations) to produce their own products; so we could temporarily use the US data to build the tool for EAD calculation.

In addition, the reason why we do use the market exchange data instead of the OTC contracts is that these types of OTC data is not public and only available

[9]Source: `http://www.interestrateswapstoday.com/swap-rates.html`.

in company's database; hence within our scope of research, they are impossible to obtain. Moreover, most of the OTC swap contracts are just an adjusted version of the standardized swaps in the market exchange; only few terms are changed to meet a demand of two traders. The structure and characteristics of the standardized swaps are almost similar to the OTC ones so using the standardized contracts as a temporary solution to generate an OTC swap portfolio is fine in this case.

6.5 Summary of Results

Table 6.5

Amount of exposure of default towards 3 counterparties

(with netting and collateral agreement)

Counterparty	Amount of EAD (with netting)	Amount of EAD (no netting)
A	\$29,637,720	\$92,604,560
B	\$38,250,400	\$107,949,900
C	\$124,619,600	\$124,619,600
Total	**\$192,507,800**	**\$325,174,100**

Table 6.5 demonstrates the result of EAD calculation for the mentioned portfolio. Current exposure method (CEM) is applied to obtain the resulted EAD, in which the risk mitigation such as netting and collateral effects is mentioned. Equation (**4.3.3**) is used to compute the netted potential future exposure and the collateral will be the proportional amount of corresponding current exposure (for these results, I illustrate the collateral equals 75% of current exposure) . Then equation (**4.3.5**) is used straightforward to compute the final EAD. All the calculation is executed by the calculator in R version 3.4.0 (2017-04-21).

As shown in the result, although the counterparty A has the highest number of contracts (5) with our party; however, the corresponding EAD value appears to be the smallest ones. On the other hand, with only 2 contracts, the counterparty C results the highest value of EAD. This is reasonable as contracts of counterparty A has very moderate notional amount (highest of $4.2 bill) compared to those of B and C. Also, the netting effect works effectively on portfolio of counterparty A (and C) since it is well-diversified. While a portfolio of counterparty C is lack of diversification (only “type 1” contracts) and hence in case of unfavorable situation, counterparty C is likely to expose the highest amount (in absence of netting effect).

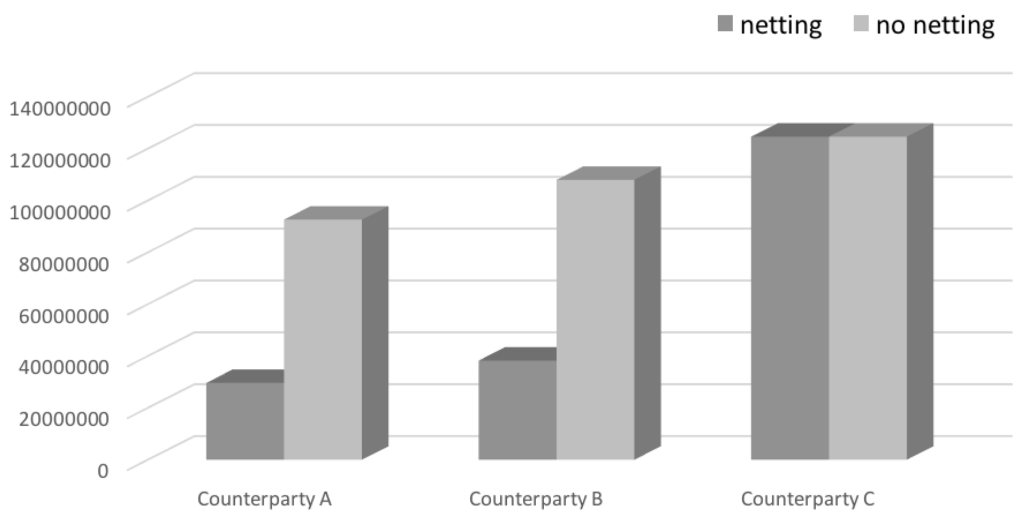

Figure 6.5

Illustration of EAD towards each counterparty reported in the Table 6.5.

6.6 EAD Sensitivity to Risk Mitigation

In this section, I will test the sensitivity of EAD to the following factors: collateral amount and netting effect.

a) EAD sensitivity to collateral amount (all other parameters are fixed)

Table 6.6

Sensitivity of EAD to collateral amount.

	Scenario			
Portfolio	1	2	3	4
Number of counterparties	3	3	3	3
Number of contracts	10	10	10	10
Netting effect	✓	✓	✓	✓
Collateral rate (% over CE)	0	0.25	0.5	0.75
Total EAD	**$232,030,000**	**$218,855,900**	**$191,681,800**	**$172,507,800**

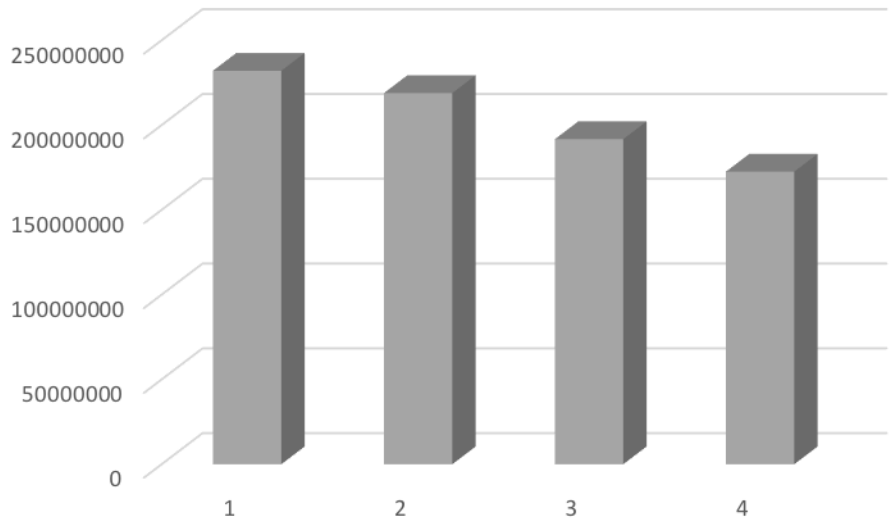

Figure 6.6

EAD amount of the portfolio in each scenario.

b) EAD sensitivity to netting effect (all other parameters are fixed)

Table 6.7

Sensitivity of EAD to netting effect.

	Scenario	
Portfolio	1	2
Number of counterparties	3	3
Number of contracts	10	10
Netting effect	×	✓
Collateral rate (% over CE)	0.25	0.25
Total EAD	**$351,522,201**	**$218,855,900**

c) EAD sensitivity to both netting effect and collateral amount (all other parameters are fixed)

Table 6.8

Sensitivity of EAD to both netting effect and collateral amount.

	Scenario			
Portfolio	1	2	3	4
Number of counterparties	3	3	3	3
Number of contracts	10	10	10	10
Netting effect	×	×	✓	✓
Collateral rate (% over CE)	0	0.25	0	0.25
Total EAD	**$364,696,268**	**$351,522,201**	**$232,029,954**	**$218,855,887**

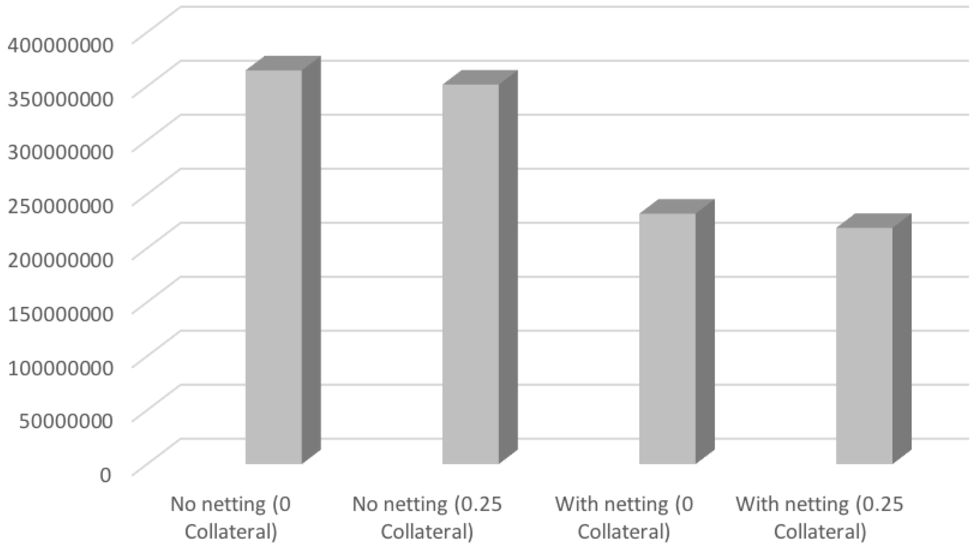

Figure 6.7

EAD amount of the portfolio in each scenario.

Based on these reported tables, it is obvious that in the presence of collateral and netting effect, the amount of EAD for the portfolio reduces significantly. Hence, these tools are called the risk mitigation and they could help banks save a considerable amount of capital reserve through lowering EAD value.

Chapter 7

Conclusion

7.1 Summary

The lessons from the past financial crisis emphasize the importance of CCR management, especially for the OTC derivatives market. In which, the enhancement of Basel framework to calculate an exposure at default is essential to determine mark-to-market losses of the derivative products and hence the CVA capital to meet the Basel requirement.

The study of the EAD measurement has been very popular in many developed financial markets where trading of derivative products is very intensive and complex. Regulations and instructions from authorities such as Basel Committee need to be explicit and comprehensive for market participants to follow. However, such kind of documents in our country are very scare and insufficient since the practice for derivative market is just at the beginning stage. This thesis, therefore, has put forward various concepts and knowledge associating to EAD approach and valuation.

The starting point of the thesis was to examine which factors lying under the EAD calculation. The EAD was shown to reply on the current exposure amount and the uncertain variability of underlying asset's value. In addition, two frameworks of the Basel Accord for EAD was introduced: the current exposure method (CEM) and the internal model method (IMM), but the major focus was on the former. Although recent studies [9] [6] show that IMM is superior to CEM, there is a fact that it is not common in practice and is only used by a few large firms , signifies that the implementation complexity sometimes outweigh the benefits.

The calculation of EAD under CEM is based on a generated IRS contracts portfolio. The results recognize the importance of risk mitigating tools (netting and collateral) reducing the EAD value. These tools help firms not only to avoid the CCR but also save a considerable regulatory capital reserve through lowering EAD value.

Finally, for CEM technique, I also offer a guidance in Excel as well as an automatic calculator in R platform for all users to compute the EAD value for the IRS contracts portfolio.

7.2 Limitation

The limitation of the thesis is that I could not directly used the real OTC data since these data are not public and only stored in the firm's database; hence, an access to them seems to be impossible. Furthermore, up to the time of this study, the derivative market in Vietnam[1] has not been established yet, so I could not have a chance to study and analyize characteristics of these products in Vietnam market.

The temporary solution; however, is that using a generated portfolio of IRS contracts, which is referenced to some characteristics of the standardized contracts in the US exchange market. This approach is reasonable as the characteristics of the OTC contracts are almost similar to the standardized ones. Also, many markets in our region, namely Thailand and Malay, have been referencing to the US derivative market (e.g.using the same USD Libor rate as reference floating rate, or same netting and collateral treatment); so we assume Vietnam will follow this trend.

[1]The derivative market of Vietnam is proposed to open at the end of May, 2017.

7.3 Recommendation for Future Work

The thesis in fact has only scratched the surface of exposure at default and its one standardized approach. In order to apply in Vietnam market, there are much more things that need to adjust and upgrade. Firstly, after the initiation of our derivative market, we need to collect real data and analyze the distinct characteristics of our product to adjust some terms in the approach of EAD calculation and CEM framework. The netting and collateral treatment may not be changing so much; however, we should modify the credit conversion factor (**4.1**) to fit our market conditions. At the early stage of the market, I do not recommend to use the complicated model like IMM as the cost and complexity maybe outweigh the advantages. For our immature market, CEM is good enough to determine the EAD value and hence the regulatory CVA capital.

Another thing that one could do is to study about the new updated version of CEM, which is the Standardized Approach for Counterparty Credit Risk method (SA-CCR). The SA-CCR imposes some netting and collateral advantages to the future exposure, which is the limit of CEM. The implementation of SA-CCR is much more effective than the CEM and also more affordable than the IMM for financial institutions.

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Appendix A

R code

A.1 main.R

```
# Author : Dinh Khanh Duy
# Date : 2017-05-24
# Purpose: Calculate EAD for IRS contracts portfolio under CEM
#
#Calculate CE for each counterparty
Value.A <- data.frame() #MTM value of each contract within cp A
Exposure.A <- data.frame() #Exposure of each contract within cp A
PFE.A <- data.frame() #Potential Future Exposure of each contract
   within cp A
Value.B <- data.frame()
Exposure.B <- data.frame()
PFE.B <- data.frame()
Value.C <- data.frame()
Exposure.C <- data.frame()
PFE.C <- data.frame()
for(i in 1:length(portfolio_data$Counterparty)){
  if(isTRUE(as.character(portfolio_data[i,1])=="A")==TRUE){
    j=length(Value.A$V1)
    if(portfolio_data[i,8]==1){
      Value.A[j+1,1]=-findPresentValue1(portfolio_data[i,3],
         portfolio_data[i,4],
                                              portfolio_data[i,7],
                                                 portfolio_data[i,9])+
```

```
      findPresentValue2(portfolio_data[i,3],portfolio_data[i,4],portfolio_data[i,7],
                        portfolio_data[i,11])
    }
    else{Value.A[j+1,1]=findPresentValue1(portfolio_data[i,3],portfolio_data[i,4],
                                        portfolio_data[i,7],portfolio_data[i,9])-
      findPresentValue2(portfolio_data[i,3],portfolio_data[i,4],portfolio_data[i,7],
                        portfolio_data[i,11])
    }
    Exposure.A[j+1,1]=max(Value.A[j+1,1],0)
    PFE.A[j+1,1]=findPFE(portfolio_data[i,3],portfolio_data[i,4])
  }
  else if(isTRUE(as.character(portfolio_data[i,1])=="B")==TRUE){
    j=length(Value.B$V1)
    if(portfolio_data[i,8]==1){
      Value.B[j+1,1]=-findPresentValue1(portfolio_data[i,3],portfolio_data[i,4],
                                        portfolio_data[i,7],portfolio_data[i,9])+
        findPresentValue2(portfolio_data[i,3],portfolio_data[i,4],portfolio_data[i,7],
                          portfolio_data[i,11])
    }
    else{Value.B[j+1,1]=findPresentValue1(portfolio_data[i,3],portfolio_data[i,4],
                                        portfolio_data[i,7],portfolio_data[i,9])-
      findPresentValue2(portfolio_data[i,3],portfolio_data[i,4],portfolio_data[i,7],
                        portfolio_data[i,11])
    }
    Exposure.B[j+1,1]=max(Value.B[j+1,1],0)
    PFE.B[j+1,1]=findPFE(portfolio_data[i,3],portfolio_data[i,4])
  }
```

```
  else if(isTRUE(as.character(portfolio_data[i,1])=="C")==TRUE){
    j=length(Value.C$V1)
    if(portfolio_data[i,8]==1){
      Value.C[j+1,1]=-findPresentValue1(portfolio_data[i,3],portfolio_data[i,4],
                                                    portfolio_data[i,7],portfolio_data[i,9])+
        findPresentValue2(portfolio_data[i,3],portfolio_data[i,4],portfolio_data[i,7],
                                portfolio_data[i,11])
    }
    else{Value.C[j+1,1]=findPresentValue1(portfolio_data[i,3],portfolio_data[i,4],
                                                    portfolio_data[i,7],portfolio_data[i,9])-
      findPresentValue2(portfolio_data[i,3],portfolio_data[i,4],portfolio_data[i,7],
                              portfolio_data[i,11])
    }
    Exposure.C[j+1,1]=max(Value.C[j+1,1],0)
    PFE.C[j+1,1]=findPFE(portfolio_data[i,3],portfolio_data[i,4])
  }
}
CE0.A = sum(Exposure.A) #Current Exposure without netting towards cp A
CE1.A = max(sum(Value.A),0) #Current Exposure with netting towards cp A
#
CE0.B = sum(Exposure.B)
CE1.B = max(sum(Value.B),0)
#
CE0.C = sum(Exposure.C)
CE1.C = max(sum(Value.C),0)
#Calculate PFE for each counterparty
PFE0.A = sum(PFE.A) #Potential future exposure without netting towards cp A
PFE0.B = sum(PFE.B)
```

```
PFE0.C = sum(PFE.C)
#
PFE1.A = (0.4+0.6*findNGR(Value.A,Exposure.A))*sum(PFE.A) # Potential future exposure with netting towards cp A
PFE1.B = (0.4+0.6*findNGR(Value.B,Exposure.B))*sum(PFE.B)
PFE1.C = (0.4+0.6*findNGR(Value.C,Exposure.C))*sum(PFE.C)
#Calculate Collateral for each counterparty in each scenario
Col_rate <- data.frame(Collateral_Table$‘Collateral rate‘)
Col.A_0 <- findCol(Col_rate[1,1],CE0.A) #Total collateral post by cp A with the rate of 0% over the current exposure
Col.A_0.25 <- findCol(Col_rate[2,1],CE0.A) #Total collateral post by cp A with the rate of 25% over the current exposure
Col.A_0.5 <- findCol(Col_rate[3,1],CE0.A)
Col.A_0.75 <- findCol(Col_rate[4,1],CE0.A)
#
Col.B_0 <- findCol(Col_rate[1,1],CE0.B)
Col.B_0.25 <- findCol(Col_rate[2,1],CE0.B)
Col.B_0.5 <- findCol(Col_rate[3,1],CE0.B)
Col.B_0.75 <- findCol(Col_rate[4,1],CE0.B)
#
Col.C_0 <- findCol(Col_rate[1,1],CE0.C)
Col.C_0.25 <- findCol(Col_rate[2,1],CE0.C)
Col.C_0.5 <- findCol(Col_rate[3,1],CE0.C)
Col.C_0.75 <- findCol(Col_rate[4,1],CE0.C)
#
#EAD cp A with no netting
EAD0.A_0 = findEAD(CE0.A,PFE0.A,Col.A_0) #no netting, 0% collateral
EAD0.A_0.25 = findEAD(CE0.A,PFE0.A,Col.A_0.25) #no netting, 25% collateral
EAD0.A_0.5 = findEAD(CE0.A,PFE0.A,Col.A_0.5)
EAD0.A_0.25 = findEAD(CE0.A,PFE0.A,Col.A_0.75)
#EAD cp A with netting
EAD1.A_0 = findEAD(CE1.A,PFE1.A,Col.A_0) #with netting, 0% collateral
EAD1.A_0.25 = findEAD(CE1.A,PFE1.A,Col.A_0.25) #with netting, 25% collateral
EAD1.A_0.5 = findEAD(CE1.A,PFE1.A,Col.A_0.5)
```

```
EAD1.A_0.25 = findEAD(CE1.A,PFE1.A,Col.A_0.75)
#EAD cp B with no netting
EAD0.B_0 = findEAD(CE0.B,PFE0.B,Col.B_0)
EAD0.B_0.25 = findEAD(CE0.B,PFE0.B,Col.B_0.25)
EAD0.B_0.5 = findEAD(CE0.B,PFE0.B,Col.B_0.5)
EAD0.B_0.25 = findEAD(CE0.B,PFE0.B,Col.B_0.75)
#EAD cp B with netting
EAD1.B_0 = findEAD(CE1.B,PFE1.B,Col.B_0)
EAD1.B_0.25 = findEAD(CE1.B,PFE1.B,Col.B_0.25)
EAD1.B_0.5 = findEAD(CE1.B,PFE1.B,Col.B_0.5)
EAD1.B_0.25 = findEAD(CE1.B,PFE1.B,Col.B_0.75)
#EAD cp C with no netting
EAD0.C_0 = findEAD(CE0.C,PFE0.C,Col.C_0)
EAD0.C_0.25 = findEAD(CE0.C,PFE0.C,Col.C_0.25)
EAD0.C_0.5 = findEAD(CE0.C,PFE0.C,Col.C_0.5)
EAD0.C_0.25 = findEAD(CE0.C,PFE0.C,Col.C_0.75)
#EAD cp C with netting
EAD1.C_0 = findEAD(CE1.C,PFE1.C,Col.C_0)
EAD1.C_0.25 = findEAD(CE1.C,PFE1.C,Col.C_0.25)
EAD1.C_0.5 = findEAD(CE1.C,PFE1.C,Col.C_0.5)
EAD1.C_0.25 = findEAD(CE1.C,PFE1.C,Col.C_0.75)
#display example results
cat("Exposure at default for cp A with no netting and 0% of
   Collateral is:" , EAD0.A_0)
cat("Exposure at default for cp A with no netting and 0.5% of
   Collateral is:" , EAD0.A_0.5)
cat("Exposure at default for cp A with netting and 0% of Collateral
    is:" , EAD1.A_0)
cat("Exposure at default for cp A with netting and 0.5% of
   Collateral is:" , EAD1.A_0.5)
```

A.2 Import_data.R

```
#Import Data
library(readxl)
USD_Libor <- read_excel("~/Desktop/a.xls", sheet = "1") #Import USD Libor spot rate
USD_Libor$`Start Date` <- as.Date(USD_Libor$`Start Date`)
USD_Libor$Maturity <- as.Date(USD_Libor$Maturity)
USD_Libor$Date <- c(seq(1:length(USD_Libor$`Rates(%)`)))
for(i in 1:length(USD_Libor$`Rates(%)`)){USD_Libor[i,5]<-USD_Libor[i,2]-USD_Libor[i,3]}
#
Eurodollar_Futures <- read_excel("~/Desktop/a.xls", sheet = "2") #Import Euro-dollar Futures rates
Eurodollar_Futures$`Start Date` <- as.Date(Eurodollar_Futures$`Start Date`)
Eurodollar_Futures$`End Date` <- as.Date(Eurodollar_Futures$`End Date`)
Eurodollar_Futures$Maturity <- as.Date(Eurodollar_Futures$Maturity)
#
portfolio_data <- read_excel("~/Desktop/a.xls",sheet = "3") #Import IRS portfolio
portfolio_data$`Leg rate receiving(%)` <- as.numeric(portfolio_data$`Leg rate receiving(%)`)
portfolio_data$`(Pay Floating) Basic Point Addition` <- as.numeric(portfolio_data$`(Pay Floating) Basic Point Addition`)
fixed_rate <-read_excel("~/Desktop/a.xls",sheet = "4")
#
CCF_Table <- read_excel("~/Desktop/a.xls",sheet = "5") #Import Credit Conversion Factor for PFE calculation
CCF_Table$`Remaining maturity` <- as.numeric(CCF_Table$`Remaining maturity`)
CCF_Table$`CCF (%)` <- as.numeric(CCF_Table$`CCF (%)`)
#
Collateral_Table <- read_excel("~/Desktop/a.xls",sheet = "6") #Import Collateral rates
```

```
Collateral_Table$`Collateral rate` <- as.numeric(Collateral_Table$`
    Collateral rate`)
```

A.3 findPresentValue1.m

```
#function for PV of all fixed CFs
findPresentValue1 <-function(a,b,c,d){
  n=as.numeric(b/(1/c))
  PresentValue <- data.frame()
  VFuture <- findFutureValue1(a,b,c)
  Discount <- findDiscountFactor1(b,c)
  for(i in 1:n){
    PresentValue[i,1]=VFuture[i,1]*Discount[i,1]
  }
  return(sum(PresentValue))
}
findFutureValue1 <- function(a,b,c){
  FutureValue <- data.frame()
  n=as.numeric(b/(1/c))
  for(i in 1:n){
    if(i != n){
      if(b==1){FutureValue[i,1] = a*fixed_rate[1,2]/100/c}
      else if(b==2){FutureValue[i,1] = a*fixed_rate[2,2]/100/c}
      else if(b==3){FutureValue[i,1] = a*fixed_rate[3,2]/100/c}
      else{FutureValue[i,1] = a*fixed_rate[4,2]/100/c}
    }
    else{
      if(b==1){FutureValue[i,1] = a+a*fixed_rate[1,2]/100/c}
      else if(b==2){FutureValue[i,1] = a+a*fixed_rate[2,2]/100/c}
      else if(b==3){FutureValue[i,1] = a+a*fixed_rate[3,2]/100/c}
      else{FutureValue[i,1] = a+a*fixed_rate[4,2]/100/c}
    }
  }
  return(FutureValue)
}
findDiscountFactor1 <- function(b,c){
```

```r
  discount <- data.frame()
  n = as.numeric((b/(1/c)))
  if(1/c==0.25){for(i in 1:n){discount[i,1] = DiscountFactor[i,1]}}
  else if(1/c==0.5){for(i in 1:n){discount[i,1] = DiscountFactor[i*
      2,1]}}
  else if(1/c==0.75){for(i in 1:n){discount[i,1] = DiscountFactor[i
      *3,1]}}
  else {for(i in 1:n){discount[i,1] = DiscountFactor[i*4,1]}}
  return(discount)
}
```

A.4 findPresentValue2.R

```r
#function for PV of Floating CFs
findTerm2 <- function(c){
  if(1/c==0.25){Value = Term2[1,1]}
  else if(1/c==0.5){Value = Term2[2,1]}
  else if(1/c==0.75){Value = Term2[3,1]}
  else {Value = Term2[4,1]}
  return(Value)
}
findRate2 <- function(c){
  if(1/c==0.25){Rate = ZeroCurve[1,1]}
  else if(1/c==0.5){Rate = ZeroCurve[2,1]}
  else if(1/c==0.75){Rate = ZeroCurve[3,1]}
  else {Rate = ZeroCurve[4,1]}
  return(Rate)
}
findPresentValue2 <- function(a,b,c,e){
  FutureValue2 = a*(findRate2(c)+e*0.01/100)*findTerm2(c)/360+a
  PresentValue2 = as.numeric(FutureValue2*findDiscountFactor1(b,c)[
      1,1])
  return(PresentValue2)
}
```

A.5 Yield_Curve.R

```r
#Construct a Yield-Curve
T1 = data.frame()
for(i in 1:length(Eurodollar_Futures$`Start Date`)){T1[i,1] <- Eurodollar_Futures[i,3]- USD_Libor[1,3]}
T2 = data.frame()
for(i in 1:length(Eurodollar_Futures$`Start Date`)){T2[i,1] <- Eurodollar_Futures[i,4]- USD_Libor[1,3]}
"T2-T1" <- T2 -T1
"Convexity Adjustment" = 0.5*(0.01^2)*(T1/365)*(T2/365)
"Future Rate (%)" = 100 - Eurodollar_Futures$`Last Quoted Price`
"Forward Rate" = (`Future Rate (%)`- `Convexity Adjustment`*100)/100
Term <- data.frame()
for(i in 1:21){if(i<=2){Term[i,1]=USD_Libor[i+1,5]}else{Term[i,1]=T2[i-2,1]}}
Rate <- data.frame()
for(i in 1:21){if(i<=2){Rate[i,1]=USD_Libor[i+1,4]/100}else{Rate[i,1]=(((1+Rate[i-1,1]*Term[i-1,1]/365)*(1+`Forward Rate`[i-2,1]*`T2-T1`[i-2,1]/365)-1)*365/Term[i,1])}}
Term2 <- data.frame()
for(i in 1:21){if(i<=2){Term2[i,1]=USD_Libor[i+1,5]}else{Term2[i,1]=Eurodollar_Futures[i-2,5]- USD_Libor[1,3]}}
ZeroCurve <- data.frame()
for(i in 1:21){if(i<=2){ZeroCurve[i,1]=Rate[i,1]}else if(i<=20){ZeroCurve[i,1]=Rate[i,1]+(Rate[i+1,1]-Rate[i,1])*((Term2[i,1]-Term[i,1])/(Term[i+1,1]-Term[i,1]))}}
DiscountFactor <- data.frame()
for(i in 1:20){DiscountFactor[i,1]=1/(1+ZeroCurve[i,1]*Term2[i,1]/360)}
```

A.6 findNGR.R

```
#function for NGR for each counterparty---------------------------------
findNGR <- function(Value,Exposure)  #Value: MTM Value, Exposure: Exposure of each contract
{
  if (all(a== 0))
  { NGR = 1
  } else if(all(a< 0))
  { NGR = 0
  } else
  {   NGR = max(sum(a),0)/sum(b)
  }
  return(NGR)
}
```

A.7 findPFE.R

```
#function for PFE for each counterparty------------------
findPFE <- function(Notional,Maturity){
  if(Maturity>1 & Maturity<5){PFE=0.5/100*Notional}
  else if(Maturity>=5){PFE=1.5/100*Notional}
  else {PFE=0}
  return(PFE)
}
```

A.8 findCol.R

```
#function for collateral for each counterprty------
findCol <- function(Collateral_rate,CE0) #CE0 :CE no netting
{
  if (Collateral_rate==0)
  { Col = 0
  } else
  { Col = Collateral_rate*CE0}
  return(Col)
}
```

A.9 findEAD.R

```
#function for Exposure at Default for each counterparty------
findEAD <- function(CE,PFE,Collateral){
  EAD = CE + PFE - Collateral
  return (EAD)
}
```