GARP Research Fellowship 2017: An analysis of the ISDA model for calculating initial margin for non-centrally cleared OTC derivatives

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Abstract

The 'global financial crisis' (GFC) highlighted the need for more effective regulation aimed at reducing the systematic risks inherent in financial markets. One of the focus areas for regulators following the crisis has been the over-the-counter (OTC) derivatives market due its sheer size and interconnectedness. In 2009, G20 leaders agreed that all standardized OTC derivatives need to be cleared by Central Counterparties (CCPs). Further, in the future, regulators will require that firms post both initial margin (IM) and working margin (WM) for non-cleared OTC derivatives. A framework developed by the ISDA, based on the recommendations of the BCBS/IOSCO Working Group on Margin Requirements (WGMR) that sets out rules for the determination of IM and WM for financial institutions, has come into effect in September 2016. The purpose of the paper is to analyse this framework and highlight its advantages and disadvantages.

Contents

1 Introduction

Following the global financial crisis (GFC), regulators have enacted numerous reforms such as Basel III, Dodd-Frank and EMIR [1] aimed at mitigating systematic risk, as well as improving the liquidity and stability of financial markets. The collapse of Lehman Brothers and the bailout of American International Group (AIG) in 2008 specifically underscored the need for more effective regulation of the over-the-counter (OTC) derivatives market due to its sheer size and interconnectedness[2]. During the 2009 Pittsburgh Summit [18], G20 leaders agreed that:

- trades in OTC derivatives should be reported to trade repositories;
- all standardized OTC derivatives should be cleared through central counterparties (CCPs), and that
- non-centrally cleared OTC derivatives should be subject to higher capital and margin requirements.

Despite regulation aimed at encouraging central clearing through CCPs, this is not always feasible as some OTC derivatives are too illiquid and not standardized for CCPs to clear. In 2013, in an effort to establish minimum global standards for margin requirements, the Basel Committee on Banking Supervision (BCBS) and the International Organization of Securities Commissions (IOSCO9) published the Working Group on Margin Requirements (WGMR) framework (BCBS-IOSCO 2013a) [20] which provides guidelines for the margin requirements for non-centrally cleared derivatives. The aim of the WGMR is to reduce spillover and contagion effects of non-cleared OTC derivatives by trying to make them imitate as closely as possible those transactions which are centrally cleared.

One of the requirements that financial institutions dealing with non-centrally cleared derivative contracts will need to take into account in complying with the new regulation is the posting of initial margin (IM) , which, according to the WGMR can neither be rehypothecated [3] nor segregated. Furthermore, due to the diversity of OTC derivatives traded as well as the lack of price discovery and liquidity, the need

[1] The European Market Infrastructure Regulation (EMIR) is a body of European legislation for the regulation of over-the-counter derivatives. The key aspects of this framework cover clearing, reporting and risk mitigation.

[2] According the Bank of International Settlements (BIS), the OTC derivatives market had a gross notional outstanding of $630 trillion in December 2014. This figure includes both cleared and non-cleared contracts.

[3] Re-hypothecation occurs when the creditor reuses the collateral posted by a debtor to back the creditor's own trades and borrowing.

for a methodology which is simple, truly reflective of risks and easily implemented becomes clear. Additionally, a common methodology would provide several key benefits to the market, such as permitting timely and transparent dispute resolution and allowing consistent regulatory governance and oversight.

In 2013, the ISDA proposed a Standard Initial Margin Model (SIMM) as an aid to market participants in determining the initial margin requirements in cases where their OTC derivatives are not centrally cleared [27]. This paper will analyse the SIMM model in depth to determine whether the above criteria are satisfied. Furthermore, the SIMM model requires every trade be classified into one of four categories (Equity, Commodity, Interest Rate and FX, Credit), and IM is calculated separately for each category. No netting of initial margin is allowed between the different product categories. Although this is a conservative approach it fails to take into account those trades which are executed but hedged with a product that is classified in a different product category. This could lead to a posting of more IM than would have been the case if netting was allowed, and possibly to a reduction in liquidity in the market.

Research objectives

Our paper attempts to:

- Implement the SIMM model with a representative portfolio of interest rate products in order to calculate the IM and net sensitivities to various risk factors,
- Compute the IM of the same portfolio using a historical VaR approach utilizing a ten-day 99% level approach for a period bracketing the financial crisis
- Compare both approaches and comment critically on the feasibility, advantages, and shortcomings of the SIMM model.

The remainder of the paper is organized as follows: Section 2 gives a brief description of the functioning of centrally cleared and OTC markets as well as an overview of reforms aimed at improving the functioning of the OTC derivatives market. The concept of IM is also introduced and different methodologies of calculating this are presented. Section 3 describes the methodology of the SIMM model. In Section 4 we construct a sample portfolio of representative products and describe the portfolio construction and any assumptions made. The results of the SIMM model are analysed as well and we consider how these results compare with traditional risk measures such as Historical VaR in calculating the amount required for the posting of initial margins. Section 5 concludes.

2 Literature Review

2.1 Organisation of Derivative Markets

According to the BIS[2], derivatives markets can be classified into three different categories. The first, the bilateral OTC market, is a fully decentralised market in which participants both trade and clear their trades directly with one another. The second is an OTC market with decentralised trading but with centralised clearing through a Central Counterparty (CCP). The third form is an exchange-based market, both trading and clearing are centralised through an exchange that is typically linked to a CCP.

2.1.1 OTC Derivative Markets

In OTC markets, derivatives are transacted bilaterally between two parties. Typically the parties transacting are classified as dealers and end-users. Dealers are usually large financial institutions such as investment banks who provide standardized products, investment and risk management solutions to clients. End-users are typically organizations such as corporates, governments and investment managers such as pension funds or hedge funds.

The gross notional amount outstanding of OTC derivatives was estimated at \$544 trillion at the end of the second quarter of 2016, 38% of which were not centrally cleared [2]. In a bilateral OTC market without central clearing, one counterparty may make demands on the other counterparty which they cannot satisfy due to insufficient funds, or at an excessive cost. This is what is referred to as liquidity risk. Additionally, market participants are exposed to counterparty credit risk as each participant faces the risk that the counterparty will fail to live up to what was contractually agreed upon. This counterparty credit risk can be limited through the use of collateral and bilateral netting agreements.

In the use of collateral, the parties limit counterparty risk by requiring the daily posting of collateral reflecting the mark-to-market changes in the value of the contracts. Collateral agreements can be customised to reflect the contracting parties' assessment both of the riskiness of the position and of each other's credit quality. The posting of collateral implies that actual counterparty exposures are smaller than market values would suggest. Surveys conducted by the ISDA indicate that roughly two-thirds of OTC derivatives exposures are collateralised and that the estimated amount of collateral in use at the end of 2008 was approximately \$4 trillion, of which almost 85% was cash (see ISDA Margin Survey (2009)[26]).

The second component of managing counterparty risk, bilateral netting agreements, helps reduce collateral requirements. The ISDA margin survey cited above indicates that virtually all large banks rely on some form of bilateral netting agreement to control counterparty exposures. In many cases, bilateral netting agreements allow for netting across different contract types.

2.1.2 Central Counterparties

A CCP can be defined as "... an entity that interposes itself between counterparties to contracts traded in one or more financial markets, becoming the buyer to every seller and the seller to every buyer."[4] The legal process whereby the CCP is interposed between buyer and seller is known as novation. Consequently, due to the process of novation, there is no need for the original counterparties to initially evaluate each others' creditworthiness. For markets utilizing a CCP, the original parties to a trade may be entirely unknown to each other.

An OTC CCP differs from an Exchange Traded (ET) CCP in that an OTC CCP will usually take credit exposure for much longer periods than an ET CCP due to the wide range of products and maturities traded in the OTC markets. Furthermore, OTC CCPs use a longer margin period of risk than an ET CCP which clears only largely liquid futures. As the CCP stands as an intermediary between the buyer and the seller it bears credit risk, however, the CCP is market-neutral and the market risk is borne by the original counterparties to the trade. In order to manage the credit risks to which it is exposed, CCP's engage in a number of credit risk mitigation strategies such as access restrictions, margining requirements and collaterization. Figures 1 and 2 on the following page show a schematic of an OTC market versus a centrally cleared market and Figure 3 shows a table of comparisons based on market characteristics.

Central clearing can create greater opportunities for netting of derivatives, and netting reduces counterparty credit risk. CCPs provide numerous benefits to the financial system including reducing informational asymmetries, providing liquidity as well as reducing systematic risk[5]. Central clearing makes it easier to facilitate regulatory oversight of the OTC derivatives market by allowing regulators to monitor the market through CCPs rather than through a complicated and large network of bilateral transactions [21].

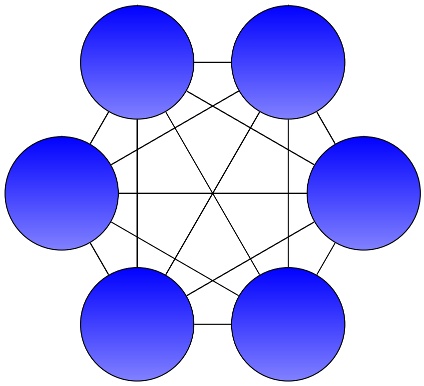

Figure 1: Schematic of the OTC derivatives market depicting a network of interconnected dealers which are represented by the shaded circles. Each dealer in turn services numerous end-users. The black lines connecting the circles represent the list of netting sets/bilateral agreements between each dealer.

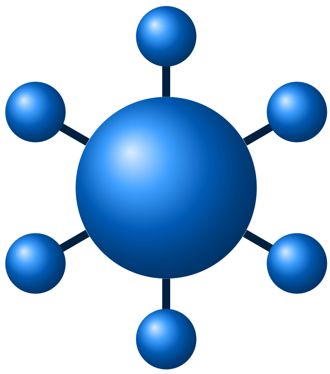

Figure 2: Schematic of a centrally cleared market. Each dealer faces a Central Counterparty (CCP) which is represented by the large central circle. Here each dealer faces the CCP instead of having separate bilateral agreements with other dealers in the market.

Three forms of market organisation for derivatives, by market characteristic			
Selected characteristic	Bilateral OTC	CCP	Exchange-based
Trading	Bilateral	Bilateral	Centralised
Clearing	Bilateral	Centralised	Centralised
Counterparty	Initial buyer or seller	CCP	CCP
Product features	All	Standardised and liquid	Standardised and liquid
Product examples	Foreign exchange swaps Interest rate swaps Credit default swaps	Plain vanilla interest rate swaps	Commodities Exchange rate futures Government bond futures
Participants	All	Typically larger dealers and higher-rated market participants	Typically larger dealers and higher-rated market participants
Market maker importance	Significant	Significant	Limited
Collateral practices	Bilateral posting of collateral	Margin requirements uniform for all	Margin requirements uniform for all
Margin movement	Decentralised and disputable	Centralised enforcement by CCP	Centralised enforcement by CCP
Risk buffers	Regulatory capital	Equity and margins	Equity and margins
Clearing and settlement	Bilateral	Centralised	Centralised
Netting	Some gross exposures netted bilaterally and some ad hoc multilateral netting	Exposures are netted multilaterally and position is against a CCP	Exposures are netted multilaterally and position is against a CCP
Regulation	Self-regulation and reliance on "market practices"	Self-regulation, reliance on "market practices" and public sector regulation of CCP	Self-regulation as well as public sector regulation of the exchanges and CCP
Transparency of exposures and activity	Limited or none	Detailed information available but not disseminated	Detailed information available but not disseminated
Transparency of prices	Pre-trade prices are non-binding quotes Actual transaction prices typically not published	Pre-trade prices are non-binding quotes No automatic publication of transaction prices	Pre-trade prices are binding quotes Actual transaction prices published

Figure 3: Comparison of characteristics between the three forms of market organisation. Note: Reprinted from "International banking and financial market developments" by S.G Cecchetti, J. Cecchetti, and M. Hollanders, September 2009, BIS Quarterly Review, page 52.

The effects of CCPs on financial markets as well as their role in risk management have led to a number of studies and collaborative efforts between the private sector, academic and regulatory bodies. These include Culp (2009)[7] and Singh (2010)[23] who look at the role of CCPs as well as analyse their benefits and costs. Duffie and Zhu (2011)[9], Stulz (2010) [24], Heller and Vause (2012)[13] and Cont and Kokholm (2014)[6] look at the effects of netting agreements and whether CCPs can reduce counterparty credit risk. Duffie et al. (2015)[8] examine CCPs in relation to the demand for collateral.

2.2 Initial Margin, Variation Margin and Collateral

IM is collateral that the holder of a financial instrument has to deposit with a counterparty when opening a position to cover some or all of the credit risk the holder poses for the counterparty. Depending on the nature of the underlying and counterparty, IM is usually around 10%-15% of the notional amount of the transaction.

Collateral in the form of IM provides reliable and timely protection in the event of a default and provides a senior claim at bankruptcy. Compared with an unsecured exposure, the use of collateral serves as a way to reduce the informational asymmetries between the borrower and lender regarding the borrower's creditworthiness. Similarly, collateral helps to align the incentives of borrowers and lenders: unsecured borrowers may have an incentive to make riskier decisions since the risk is ultimately borne by the lender; secured borrowers, by contrast, risk losing their collateral. Consequently, the collateral posted should be of high quality with low liquidity, market and credit risks. Government backed securities such as Treasuries and cash (USD, EUR, GBP, JPY) are the most popular sources of collateral.

Variation margin (mostly in the form of cash) is usually posted at least daily in order to reflect the mark-to-market price changes on outstanding positions. Initial margin is collected to cover, with a high probability (typically at least a 99 percent confidence level), potential future exposure arising between the last variation margin (VM) payment and the closeout or replacement of a defaulted counterparty's trades. Initial margin requirements may be posted either in cash or using high-quality non-cash assets that carry low credit, market and liquidity risk. The use of IM serves as an insurance against credit risk in the event that a counterparty defaults.

For instance, consider the case where Party A and Party B enter into an OTC derivatives contract. Either counterparty B will pose credit risk to party A, or vice-versa, or both, depending on the nature of the underlying derivative. Consider a simple European equity put option. If Party A has bought this put option from Party B, it has paid for the right to exercise the option when it is in-the-money at maturity. Suppose that Party B defaults prior to maturity, therefore Party A has to replace this contract with a new contract in the market with the same features and terms as the original contract. If Party A is able to make this purchase quite soon after the default, and if the market has not moved considerably since, then this price will be quite similar to the mark-to-market of the position at default. However, if there are delays in the process due to legal or operational procedures or lack of liquidity in the market, the price of entering into a new contract might be substantially higher if the underlying instrument has decreased in price. The use of collateral in the form of IM serves as a means to reduce these costs in such scenarios.

In the event of default, the surviving counterparty is exposed to possible losses from the time the default occurs right up until the time the contract is liquidated or replaced [16]. Due to the IM being posted by both counterparties, the IM provided by the default counterparty can help cover some of the losses faced by the surviving counterparty. Effectively, the posting of IM reduces moral hazard in the market by aligning the incentives of both counterparties, and in the event of default it is not only the survivor who pays [1].

According to Singh (2013)[23], the expansion of clearing via Central Counterparties (CCP's) from OTC derivative markets and the margining of non-centrally cleared derivative transactions will result in an increased demand for high-quality assets and affect the operations of collateral markets. Various studies have attempted to quantify the increase in demand. See, for example, Heller and Vause (2012) [13]; Levels and Capel (2012)[15]; Sidanius and Zikes (2012) [22]; and Duffie, Scheicher, and Vuillemey (2014) [8]. These studies have delivered a wide range of estimates, which largely reflect assumptions about the underlying volatility of OTC contracts, the share of the market that is centrally cleared, and the netting efficiency of alternative clearing arrangements[12].

The move towards centralized clearing has also raised concerns about the costs that would be incurred in supplying collateral by market participants in order to support their derivatives transactions. For instance, a study undertaken by Levels and Capel [15] quantifies the trends in demand for and supply of collateral and concludes that collateral is likely to become scarcer but not scarce in absolute terms. They argue that increased collateral scarcity will create pressure on the prices of high-quality assets due to the holdings of large portfolios of high-quality liquid assets by large financial institutions on their balance sheet.

2.3 Existing Methods for the Determination of Initial Margin

Numerous approaches exist for the determination of IM and various exchanges/C-CPs have different methodologies and models in place for the determination initial margin. These approaches can be broken down into two groups: scheduled-based approaches and model-based approaches.

2.3.1 Schedule-based approach

The schedule-based approach has been identified as one of the methods for margin calculation by the WGMR. With this approach, each trade in a counterparty's portfolio must be assigned to one of the asset class categories as defined by the exchange/regulator/CCP. This assignment is based on its primary risk factor, which must be clearly identifiable. If it is not possible to identify the primary risk factor then it is calculated using the highest IM weight within the relevant category. Certain fixed income products have a maturity dependent add-on, meaning that as time passes the product moves from one risk factor bucket add-on to another. An example of an SBA table can be found in Appendix A. The IM calculation procedure can be broken down into two steps.

The first step is the calculation of the Gross Initial Margin (GIM) which takes into account the IM of each trade. For a netting set of N trades the Gross Initial Margin (GIM) is calculated as follows:

$$GIM = \sum_{i=1}^{N} w_i p_i$$

where w_i is the add-on weight applied according to the product class and p_i is the notional amount which is always positive. The second step involves the calculation of the Net Initial Margin (NIM) which is the actual amount of IM that has to be posted. This calculation attempts to take into account the diversification of the netting set into account.

$$NIM = (0.4 + 0.6 * NGR) * GIM$$

where NGR is the ratio of the net current replacement cost of the netting set to the gross current replacement cost of the netting set, and is calculated using the formula:

$$NGR = \frac{\left|\sum_{i=1}^{N} V_i\right|}{\sum_{i=1}^{N} |V_i|}$$

where V_i is the replacement value of the portfolio. One of the disadvantages of the schedule-based approach is that it does not allow netting between different product classes, which could lead to the posting of more margin than necessary. For example, if a bank is hedging a CDS position with an interest rate swap, it would need to post initial margin for both the CDS and the hedge leading to an overly conservative figure. An alternative method for calculating the NIM has been proposed by O'Kane (2016)[19] which calculates the initial margin to be posted as a function of the value of the netting set with respect to market risk factors and sensitivity to these risk factors. The advantage of the O'Kane methodology is that it takes into account the riskiness of the position directly from the DV01, which is determined by the market instead of an arbitrary schedule of add-ons.

$$ANIM = 50bps * \left|\sum_{i=1}^{N} DV01_i\right|$$

2.3.2 Model-based approaches

Parametric Models

SPAN Standardized Portfolio Analysis of risk (SPAN) was developed in 1988 by Chicago Mercantile Exchange Inc. to effectively assess risk on an overall portfolio basis. SPAN's risk-based margin requirements allow for effective margin coverage while preserving the efficient use of capital. The model assesses the risk of a portfolio by calculating the maximum likely loss that could be suffered by the portfolio, based on parameters set by the relevant the margin-setting authority, which is usually an exchange or clearing organization [14].

Most clearinghouses use 16 scenarios in the calculation of margin requirements. Each scenario is referred to as a Risk Array. SPAN Risk Arrays represent a contract's hypothetical gain/loss under a specific set of market conditions from a set point in time to a specific point in time in the future and is comprised of a different market simulation, moving the underlying price up or down and/or moving volatility up or down. The risk array representing the maximum likely loss becomes the Scan Risk for that portfolio.

Models based on VaR-like measures (HistVaR and Simulated VaR) VaR (Value at Risk), unlike SPAN, can use any number of scenarios, and this is typically only restricted to the number of historical data points available. Today's risk factors (e.g. interest rate yields or equity prices) are shifted by an amount determined by how they have moved historically. The Market Value (MV) of the portfolio is recalculated under all shifted scenarios, and the differences between these and the original Portfolio MV are calculated.

These differences are then ranked in order (from smallest MV difference to the largest MV difference), and the VaR requirement for the portfolio margin is determined by where the clearing house wants to cut off this distribution of losses. For example, if the clearing house uses a 99% VaR model, then the VaR requirement is the portfolio MV difference value that 99% of the scenarios fall above (and 1% of the scenarios fall below). This percentage cutoff is called the "confidence level" [14].

Another way to calculate VaR is based on a simulated approach which will be explained with an example using a simple European Interest Rate Swaption with a notional of 100mm USD, Strike 0.04 with the following characteristics:

- Valuation Date: 21/07/2008
- Option Exercise Date: 21/07/2013
- Swap Maturity Date: 21/07/2018

Interest rates are stochastic and cannot be predicted with certainty. However, based on historical data we can obtain some information about how much they are likely to move and based on this and on historical prices of interest rate derivatives such as swaps and caps, we are able to obtain a market-based estimate of future volatility. By constructing a range of scenarios for what interest rates could be in future, we are able to get a sense of what the individual derivatives would be worth in those situations and form an idea of the expected exposure and potential future exposure of our portfolio.

In order to calculate the VaR using the second approach, we simulate 10,000 random interest rate paths. These scenarios are simulated using using the Hull-White one-factor model through the use of a trinomial tree. The Hull-White one-factor model describes the evolution of the short rate and is specified using the zero curve, alpha, and sigma parameters for the below equation:

$$dr = [\theta(t) - \alpha(t)r]dt + \sigma(t)dW \tag{1}$$

where:

- dr is the change in the short-term interest rate over a small interval, dt.
- r is the short-term interest rate,
- $\theta(t)$ is a function of time determining the average direction in which r moves, chosen such that movements in r are consistent with today's zero coupon yield curve,
- α is the mean reversion rate,
- dt is a small change in time,
- σ is the annual standard deviation of the short rate, and
- W is the Brownian motion component.

The parameters can be calibrated, for example, by minimizing the difference between the observed market price of a particular instrument (in this case, swaptions) and the prices obtained using known pricing method, (i.e a trinomial tree) to value the swaptions [4] . Once obtained, each of the simulated rate paths can then be used to value the derivative of interest.

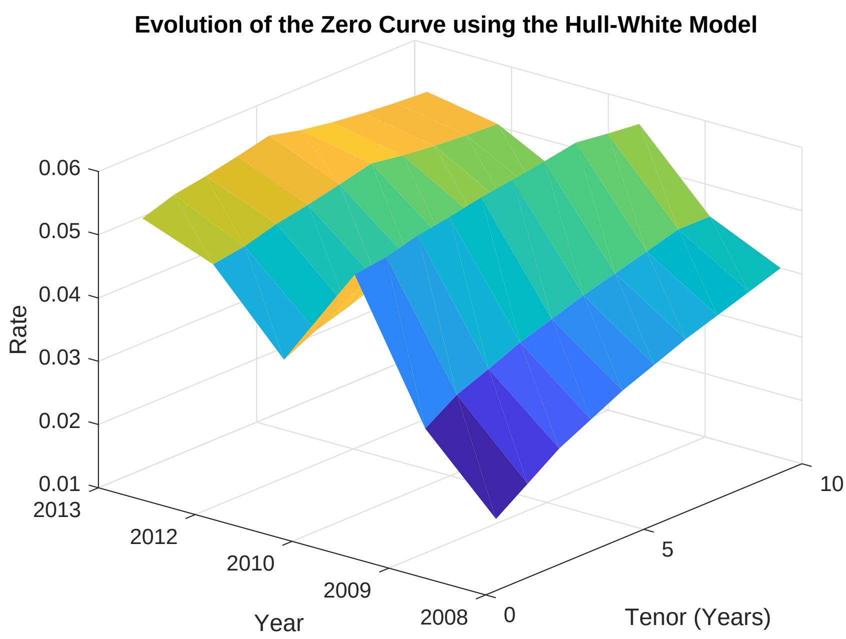

Figure 4: Sample Zero Curve obtained using the Hull-White Model.

[4]Values for σ and α are 0.0967 and 0.0088 respectively and were obtained with the Matlab function swaptionbyhw.m and the Optimization Toolbox.

- The credit exposure is the positive value of the underlying instrument.
- The Expected Exposure (EE) is the average of the credit exposure across all scenarios.
- The Potential Future Exposure (PFE) is the measure of the credit exposure with some degree of confidence. For example, the 99% PFE is the credit exposure that will not be exceeded in more than 1% of the scenarios.

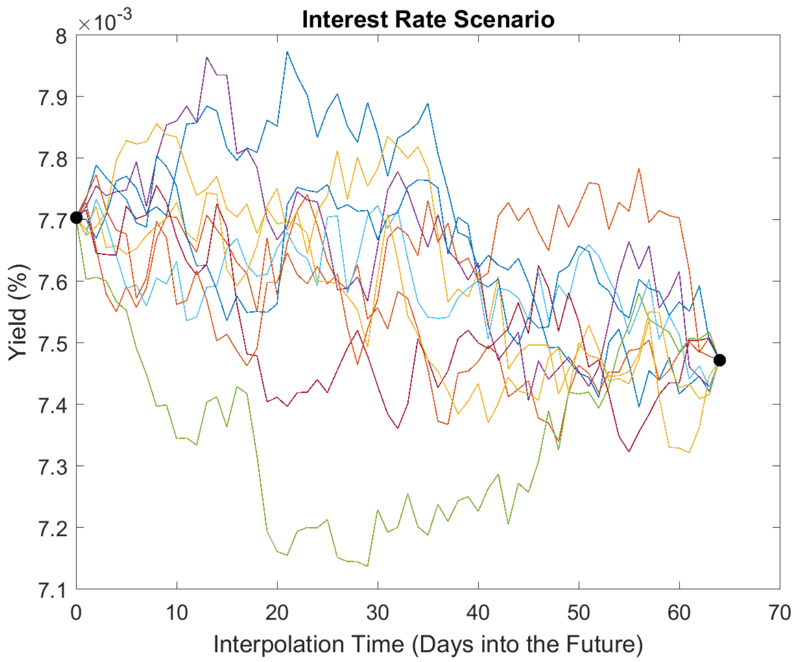

Figure 5: Simulated Interest Rate Paths using the Hull-White Model for ten sample paths.

Once the derivative is valued at each interest rate path, the value of each credit exposure is sorted from smallest to largest as displayed in Figure 6. The upper tail is chosen instead of the lower tail because the distribution is that of the value of the netting set and a loss scenario occurs when this netting set increases. The upper tail is chosen at the at the 99% level of confidence. This value represents the IM to be posted.

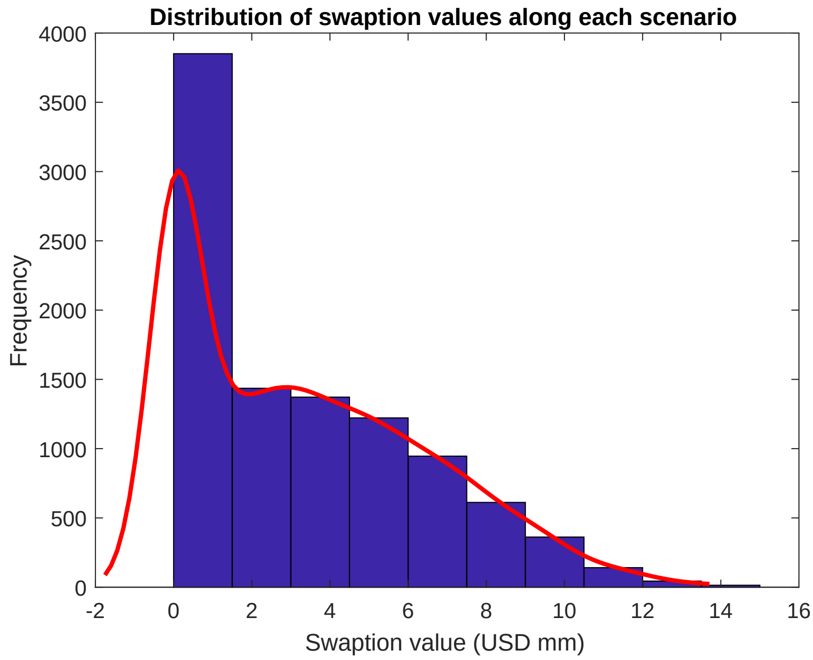

Figure 6: Histogram showing the distribution of market values of a simple swap based on 10,000 random interest rate scenarios

2.4 OTC Derivatives Reforms

The global financial crisis that began in 2007 exposed significant weaknesses in the resiliency of financial institutions to economic shocks. Moreso, it demonstrated the need for more transparency in the OTC derivatives markets and further regulation of market participants would be necessary to reduce excessive risk-taking. In response, the Group of Twenty (G20) initiated a reform programme in 2009 to reduce the systemic risk from OTC derivatives. Following this, in 2011, the G20 agreed to add margin requirements on non-centrally cleared derivatives to the reform programme and the Basel Committee on Banking Supervision (BCBS) and the International Organization of Securities Commissions (IOSCO) were tasked with developing global standards for these margin requirements.

In 2013, the policy framework that established minimum standards for margin requirements for non-centrally cleared derivatives agreed upon by the BCBS and IOSCO after consultation with various stakeholders. The policy is described in BCBS-IOSCO (2013).[20] In order to facilitate the introduction of the policy guidelines, the ISDA proposed a Standard Initial Margin Model (SIMM) which could be used by market participants. The model is presented in ISDA (2013). The latest version

R1.2 came into effect in September 2016 in the US, Japan and Canada and the effective date for the EU Rules was February 2017. This standard methodology has several key benefits to the market, such as permitting timely and transparent dispute resolution and allowing consistent regulatory governance and oversight. Very few academic papers have studied the ISDA SIMM model and its implications empirically. O'Kane(2016)[19] examines the SIMM methodology and concludes that the requirement to split the netting set by principal asset type fails to recognise the fact that many OTC derivatives have exposures to different risk types, and this penalizes hedging. He argues for calculating portfolio-wide IM's for each risk type and then summing up the portfolio risk-type IMs.

In response to the various reforms proposed for OTC derivatives markets, several academics have tried to provide insight into the implications of these reforms. Ghammami and Glasserman (2016)[11] argue that three factors play a role in comparing the costs between fully bilateral versus fully centrally cleared markets:

- the degree of netting achieved in each case;
- the margin period of risk (MPOR) used to set initial margin and capital requirements in each case, and
- CCP risk management practices - specifically, their relative reliance on initial margin and guarantee fund contributions.

Duffie and Zhu (2011)[9] examine how the introduction of CCPs into a formerly bilateral OTC world affects the netting efficiency and counterparty risk of trades. They conclude that if the CCP is established only in one derivative class while all other products remain bilaterally traded then netting efficiency is reduced, collateral demand goes up and average counterparty default exposure goes up. They demonstrate that a single CCP is more efficient than several CCPs and argue that a case where each product class has its own CCP is less efficient than the situation where there is one single CCP handling all product classes. Expanding on the methodology of Duffie and Zhu, Cont and Kokholm (2014)[6] analyse the effect of taking into account correlations and changing volatilities between various asset classes and find that the introduction of central clearing is beneficial for those assets that are highly volatile and which are highly correlated with other asset classes, even in the case where the number of CCPs is small.

3 The SIMM Model

The following section details the background, motivation and the calculation methodology for the determination of Initial Margin under the ISDA Standard Initial Margin Model (SIMM) [29] for OTC derivatives which are not centrally cleared.

3.1 Background & Objectives

In 2011, the G20 called upon the BCBS and IOSCO to develop, for consultation, consistent global standards for margin requirements for non-centrally cleared derivatives. To this end, the BCBS and IOSCO, in consultation with the CPSS [5] and CGFS [6], formed the Working Group on Margining Requirements (WGMR) in October 2011 to develop a proposal on margin requirements for non-centrally cleared derivatives for consultation by mid-2012. In July 2012, an initial proposal was released for consultation, followed by an invitation to comment on the proposal by 28 September 2012. A quantitative impact study (QIS) was undertaken to determine the potential liquidity and other impacts associated with mandatory margining requirements. In order to comply with BCBS-IOSCO guidelines, the ISDA announced in December 2013 the start of an industry-wide initiative to develop a standard initial margin model which could be used by market participants to determine the calculation of IM.

The use of a common framework for the determination of IM quantification would have several key benefits, including the more efficient planning and management of firms' liquidity needs from margin calls, timely and transparent dispute resolution as well as consistent regulatory governance and oversight. [4] Moreso, the common framework enables more efficient resolution of disputes compared to the case where each participant developed its own IM model instead. In the absence of a common methodology, each market participant would need to be able to build and maintain IM models for each of its counterparties, which would be both operationally cumbersome and counter to the regulatory objectives set in place. The latest iteration of the SIMM Methodology is version R2.0 [29] with an effective date of December 4, 2017. This document is available on the ISDA website[7].

[5] Committee on Payment and Settlement Systems
[6] Committee on the Global Financial System
[7] https://www2.isda.org/functional-areas/wgmr-implementation/

3.2 Criteria & Constraints

ISDA has identified the following key criteria to which an initial margin model aimed at satisfying the BCBS-IOSCO rules should adhere [30]. These include:

1. **Non-procyclicality** - Margins are not subject to continuous change due to changes in market volatility;

2. **Ease of replication** - Easy to replicate calculations performed by a counterparty, given the same inputs and trade populations;

3. **Transparency** - Calculation can provide contribution of different components to enable effective dispute resolution;

4. **Quick to calculate** - Low analytical overhead to enable quick calculations and re-runs of calculations as needed by participants;

5. **Extensible** - Methodology is conducive to addition of new risk factors and/or products as required by the industry and regulators;

6. **Predictability** - IM demands need to be predictable to preserve consistency in pricing and to allow participants to allocate capital against trades;

7. **Costs** - Reasonable operational costs and burden on industry, participants, and regulators;

8. **Governance** - Recognizes appropriate roles and responsibilities between regulators and industry;

9. **Margin appropriateness** - Use with large portfolios does not result in vast overstatements of risk. Recognition of risk factor offsets within the same asset class

The calculation of IM could involve numerous shocks and re-calibrations depending on the underlying instruments and thus a full price re-evaluation calculation could be computationally burdensome and time intensive. The need for the SIMM model to be able to approximate the response to these shocks speedily for derivative pricing becomes clear. As per ISDA [27], the most efficient way to approximate a derivative contract's response to shocks is to pre-compute a sensitivity or "delta" of the derivative contract for each risk factor, and approximate the response by multiplying each sensitivity by the respective risk factor shock size. [30] The model thus needs to be able to capture the systematic risks while at the same time minimize implementation costs.

3.3 Specification of the SIMM Model

The ISDA Risk Committee (RCM) was tasked with investigating the suitability of existing banking capital models as well as the approaches used for derivatives which are centrally cleared.

3.3.1 Capital Models and Traditional IM Models

With the capital model, an institution calculates the Expected Positive Exposure (EPE) to its counterparty in order to estimate the amount of credit risk capital to hold. This amount is a function of the counterparty's probability of default (PD) as well as the loss-given-default (LGD). However, unlike the risk mitigation provided by IM, the credit risk capital model requirement is imposed on the surviving counterparty only and, consequently, the capital calculations need not be reconciled. Hence, capital model outputs do not require the same level of standardization as IM. The ISDA RCM had to look beyond the traditional capital models for SIMM. These include Historical VaR simulations, the SPAN margin system, and standardized approaches which are all examples used by CCPs to compute IM amounts for their clients.

After examining numerous approaches the ISDA RCM settled on a form of the Sensitivity Based Approach (SBA), similar to the methodology adopted by the BCBS for calculating capital requirements under the revised market risk framework; i.e. the Fundamental Review of the Trading Book (FRTB). The following have been identified as potential advantages of an SBA:

- **Lower implementation and maintenance costs-** The SIMM is relatively parsimonious in its data requirements; it makes use of a "tiered" approach which first computes capital for various "buckets" using a standard Variance-Covariance formula, and then combines the bucket-level numbers using a modified Variance-Covariance formula which recognizes hedging and diversification across the buckets and currencies. This avoids the need for a large covariance matrix covering all the risk factors, and keeps the calculation modular.
  Correlation parameters have been provided by the ISDA thus avoiding the need for institutions to access historical data and for the associated licensing costs.

  Computationally the ISDA is effective from the stand-point where initial margin calculations are values from a sensitivity based approach instead of running thousands of Monte-Carlo simulations. Further, simple assumptions in terms of distributions (Gaussian) and the restricted risk coverage (e.g. dividend risk and interest rate skew are not captured) makes it effective from a modelling perspective.

- **Non-procyclicality-** The most common risk models (such as historical simulation for example) are pro-cyclical in the sense that margin requirements for the same portfolio are higher in times of market stress and lower in calm markets. This procyclicality can cause liquidity stress whereby parties posting margin have to find additional liquid assets, often at just the times when it is most difficult for them to do so[17]. The SIMM avoids this drawback in that procyclicality only comes from the regulatory requirement to automatically recalibrate the model with certain frequency.

3.4 The FRTB and SIMM

In January 2016, the Basel Committee on Banking Supervision (BCBS) published its latest version of the Standards for Minimum Capital Requirements for Market Risk which is also known as the Fundamental Review of the Trading Book (FRTB) [25]. These new standards replace certain portions of the Basel 2.5 reforms, introduced in 2009 to address the under-capitalization of some banks trading book exposures during the GFC. The FRTB specifies two approaches for calculating capital requirements for the trading book: a Standard Approach (SA) or an Internal Model Approach (IMA) which needs to be approved by the bank or regulatory supervisor at a trading desk level.

The Standard Approach (SA) makes use of risk sensitivities as inputs for determining capital requirements. Sensitivities include capital charges for delta, vega, and curvature risks and assets are segregated into different underlying risk classes such as General Interest Rate Risk (GIRR), Commodity, FX, Equity, and Credit Spread. Certain risk classes such as the Credit Spread class include the addition of a Default Risk Charge (DRC) which takes into account default risk accounting for hedging effects. A residual risk add-on (RRAO) is further applied to instruments which have non-linear pay-offs. The procedure of the SA involves the below steps:

- Delta, vega and curvature sensitivities are calculated by mapping instruments to a set of regulatory risk factors to which various shocks are applied.

- The weighted sensitivities are aggregated within each bucket using prescribed correlations and an aggregation formula.

- The resulting bucket-level capital charges are aggregated to determine a risk class level charge.

- The aggregate charge is the simple sum of each risk-class charge.

Numerous similarities between the FRTB Standard Approach and the SIMM model exist, with the SIMM model borrowing heavily on the structure of certain calculations such as sensitivities and nested variance and covariance formulae to calculate margin/capital. This may have been a deliberate decision on the part of the ISDA in order to align the risk-management procedures for a bank's trading book with its margin posting activities. A notable difference between SIMM and the FRTB methodology is that the SIMM model is based on a 99% VaR value whereas the FRTB is based on 97.5% Expected Shortfall.

3.5 Product and Risk Classes

Under the SIMM, every trade is required to be assigned to a specific product class, and for each of these product classes the IM is calculated separately. The ISDA classifies four different product classes:

- Commodity
- Credit
- Equity
- Interest Rates and Foreign Exchange (RatesFX)

Determining the amount of IM for each product class requires the calculation of various sensitivities for a number of risk classes. The current framework identifies the following six risk classes:

- Credit (Qualifying)
- Credit (Non-Qualifying)
- Commodity
- Equity
- FX
- Interest Rate

3.6 Structure of Margin Calculation

Both the FRTB Standardized Approach (Sensitivity Based Approach) and the ISDA SIMM use a sequence of nested variance/covariance formulas to calculate capital and margin. In the SIMM model, IM is calculated for each of the risk classes using the below formula:

$$IM_X = DeltaMargin_X + VegaMargin_X + CurvatureMargin_X$$

The IM for each product class is then obtained by the following formula:

$$SIMM_{product} = \sqrt{\sum_r IM_r^2 + \sum_r \sum_{s \neq r} \phi_{rs} IM_r IM_s} \tag{2}$$

where r and s are summed over each of the six risk classes and ϕ_{rs} is correlation between the risk factors which has already been specified by the ISDA and which can be found in the ISDA documents. A mathematical justification for the use of the above nested variance/covariance formula is provided by the ISDA, but the basic idea is that each IM_r^2 term represents the squared losses for each risk class, the sum of which are added together. The second term takes into account the correlation between different risk factors within a product class and specifies how much additional margin needs to be posted to account for these correlation effects. The correlation parameters range from 12.90% to 98.90%.

The overall IM to be posted is the sum of each of the four product class SIMM values:

$$SIMM = SIMM_{Credit} + SIMM_{Commodity} + SIMM_{Equity} + SIMM_{RatesFX}$$

3.6.1 Margin Period of Risk (MPOR)

The amount of IM posted would need to serve as protection against a potential future exposure (PFE) where the cost of closing out a netting set of trades exceeds the amount of collateral held in VM. This potential loss is both unknown today as well as at the time of default. Therefore there is a need to construct a model which can quantify the possible distribution of losses and to extract from that a tail risk amount with some defined confidence level. According to ISDA, this approach ensures the shocks applied to each risk factor provide 10-day cover 99% of the time over a period of history, and then with a sensible aggregation function, portfolio margins will also meet that standard. Typically, back-testing is applied to simple portfolios containing a single risk factor to assert the input shocks are sufficient, and then to balanced pairs of risk factors to assert offsets are not overly generous.

This model forms what is called by ISDA a "margin cover assertion" or MCA, which will achieve a cover standard for all portfolios given it does so for single risk factor portfolios and for balanced pairs of risk factors, while avoiding the need to check the margin scheme against all possible portfolios. Furthermore, the MCA cover standard should be consistent. Unlike Expected Shortfall (ES) which is a consistent risk measure, VaR is not[8]. ISDA maintains that while VaR is not consistent, it is typically nearly consistent, and that, the cover achieved by adding two portfolios that meet a 99% cover standard, will be nearly 99% in practice. Furthermore, the upper tail is chosen rather than the lower tail as resulting distribution is the value of the netting set and a loss scenario occurs when the value of this netting set increases.

3.6.2 Risk Factors & Sub-yield Curves

One of the conditions that the MCA standard is required to satisfy is that it should span all the randomness or risk of all portfolios under consideration. For example, with listed futures or commodities, a risk factor can be supplied for each future or commodity provided that the number of futures expirations is not too large. For equity options and futures, a single volatility shift risk factor is used.

For interest rate instruments, Principal Component Analysis (PCA) or a list of the most commonly traded tenors such as 5yr or 10yr maturities, for example, could be used as proxies for the risk factors. The ISDA have used the following three components which have an explanatory power of around 99.5%. These are: parallel shifts, curve rotations or twists, and curve bends.The challenge is to keep the number of risk factors parsimonious while at the same time ensuring that most of the potential risks do not go uncaptured. The risk factors chosen by ISDA for the Interest Rate class are the 12 yields at the following vertices, for each currency: 2 weeks, 1 month, 3 months, 6 months, 1 year, 2 years, 3 years, 5 years, 10 years, 15 years, 20 years and 30 years.

With regard to the yield curve, the ISDA has mandated the use of various sub-yield curves for the discounting and projection of cash-flows in order to value the respective derivative instruments. These are the sub-yield curve specified by the ISDA Risk Committee: OIS, Libor1m, Libor3m, Libor6m, Libor12m and (for USD only) Prime. These are the most commonly used sub-yield curves in industry which

[8] A coherent risk measure is a function that satisfies properties of monotonicity, sub-additivity, homogeneity and translational invariance.

ensures a level of standardization which is one of the goals of the SIMM model. Any sub curve not given should be mapped to its closest equivalent.

3.6.3 The Greeks

The ISDA Committee responsible for developing the SIMM model contend that the most efficient way to approximate a derivative contract's response to shocks is to pre-compute a sensitivity or delta of the derivative contract for each risk factor. The result of this is obtained by multiplying each sensitivity by the respective risk factor shock size. For example, if the risk factor for an equity call option is a spot price change in the equity price, then the sensitivity is generally known as the "Delta". For the above option, a large component of the margin would be the delta of the option times the shock size for the underlying stock price change.

The ISDA refers to the set of portfolios sensitivities to each of the risk factors as the portfolios Greeks. By making use of these Greeks the application of the scenario shocks to a derivatives portfolio now becomes a simple matter of multiplication and addition, and can thus be done quickly and is easily checked for errors, when compared to a full re-evaluation. ISDA splits the calculation of the Greeks into 3 steps:

- Step 1: Calculate the portfolio Greeks to each of the risk factors. Each firm can do this using their proprietary models, a vendor-supplied model, or their counterpart could provide the Greeks if necessary. This step will take a considerable amount of time and computational resources, and is best done overnight.
- Step 2: For each scenario, for each risk factor, multiply the scenario's risk factor's shock by the portfolio's sensitivity to that risk factor, and sum the results across the risk factors for that scenario: simple multiplication and addition, leading to a result for each scenario.
- Step 3: Apply the aggregation function to the scenario results: generally not much more complicated than step 2.

3.6.4 Definition of Sensitivity

The main inputs of the SIMM model are the sensitivities to different risk factors, which can be defined as follow:

Interest Rate and Credit:

$$s = V(x + 1bp) - V(x) \tag{3}$$

For Equity, Commodity, and FX risk:

$$s = V(x + 1\%.x) - V(x)$$

Where s is the sensitivity to the risk factor x, V(x) is the value of the instrument, given the value of x.

The actual calculation of sensitivity may differ in terms of the shock size, the type of difference method(central or backward).

3.6.5 Delta Margin Calculation

There exist two kinds of procedures to calculate the delta margin. One is for interest rate risk class and the other is for non-interest risk classes.

Interest Rate Risk Class: The delta margin for interest rate risk class should be calculated using the following steps:

1. Calculate the net sensitivity $s_{m,i}$ to each of the risk factors(m,i), where m is the rate tenor and i is the index name of the sub yield curve, which is predefined by ISDA. The rational and choices of the risk factors have been previously discussed in section 3.6.2. The reasoning behind choosing the net sensitivity is due to the SIMM model being an SBA methodology, which, as explained in section 3.3.1, has low maintenance costs and is computationally efficient to calculate.

2. Calculate the weighted net sensitivity by the following formula:

$$WS_{m,i} = RW_m * s_{m,i} * CR_b$$

   where the RW_m is the risk weight predefined by ISDA which can be found in Appendix B.1. This is classified according to the currency of each sub-yield curve. ISDA classifies three categories of currencies: regular currencies [9], low volatility currencies (JPY) and volatile currencies (currencies not belonging to the previous two groups). CR_b is a concentration risk factor, which can be calculated as:

$$CR_b = \max\left(1, \left(\frac{|\sum_{m,i} s_{m,i}|}{T_b}\right)^{\frac{1}{2}}\right) \tag{4}$$

[9] US Dollar (USD), Euro (EUR), British Pound (GBP), Swiss Franc (CHF), Australian Dollar (AUD), New Zealand Dollar (NZD), Canadian Dollar (CAD), Swedish Krona (SEK), Norwegian Krone (NOK), Danish Krona (DKK), Hong Kong Dollar (HKD), South Korean Won (KRW), Singapore Dollar (SGD), and Taiwanese Dollar (TWD).

where the term inside the square root represents the magnitude of the net interest rate sensitivity (summed over the different curves of different tenors) of the netting set divided by the ‘concentration threshold T_b which is the predefined threshold (represented in USD mm/bp) for each currency b. For example, for the low volatility currency category (JPY) this threshold is USD 17mm. The maximum function ensures that the concentration factor is capped at 1 offering no real benefits to portfolios which are finely concentrated, and at the same time ensuring that the WS at the product level increases if a portfolio is highly concentrated with respect to exposure to the risk factors. This concentration factor is proportional to the ratio of the square root of the sum of the absolute value of sensitivities to the ISDA's pre-defined threshold, which can be found in Appendix B.3.

The reason for using a risk-weighted measure is that some tenors, depending on the type of currency of the underlying instrument, are considered to be more risky and volatile, and therefore have higher weights. Moreover, the SIMM model takes into account how concentrated a portfolio is with respect to certain currencies. For example, Formula 8 indicates if the absolute sum of the weighted sensitivities in a specific currency exceeds the threshold for that currency, denoted by T_b, then we place more weight to weighted sensitivity. This intuitively makes sense if the portfolio is heavily exposed to volatile currencies, then the SIMM model will demand higher IM.

3. Aggregate weighted sensitivities within each currency:

$$K = \sqrt{\sum_{i,m} WS_{m,i}^2 + \sum_{i,m} \sum_{(j,n)\neq(i,m)} \phi_{i,j}\rho_{m,n}WS_{m,i}WS_{n,j}}$$

where $\phi_{i,j}$ is the sub-curve correlations parameters and the $\rho_{m,n}$ are the tenor correlation parameters, which are set out in Appendix B.2. The use of correlation parameters ensures that diversification benefits are realised within risk factor classes of a particular currency. The correlation parameters have been set by ISDA, and any implementation will take into consideration future changes in these values.

4. Calculate the Delta Margin by aggregating the currency level sensitivity within the Interest Rate risk class across currencies:

$$DeltaMargin = \sqrt{\sum_b K_b^2 + \sum_b \sum_{c\neq b} \gamma_{bc} g_{bc} S_b S_c} \tag{5}$$

where,

$$
\begin{aligned}
S_b &= \max(\min(\sum_{i,m} WS_{m,i}, K_b), -K_b) \\
g_{bc} &= \frac{\min(CR_b, CR_c)}{\max(CR_b, CR_c)} \\
\gamma_{b,c} &= 27\%
\end{aligned}
$$

Equation 5 takes a variance-covariance approach to the overall delta margin calculation, taking into account diversification across currencies. This is achieved by S_b which ensures the diversification benefits are indeed realized which has the advantage that it cannot exceed the bounds of $\pm K_b$. The inclusion of g_{bc} is to ensure that the margin posted is not excessive as this amount will always be less than one.

Non-Interest Rate Risk Classes: For Non-Interest Rate risk classes, the calculation methods are similar. The main difference is the calculation of sensitivities to different risk factors. The details can be found in ISDA documents.

3.6.6 Vega Margin and Curvature Margin Calculation

Instruments that are options or include an option are subject to additional margin requirement to account for vega risk and curvature risk.

The Vega Margin can be obtained by following steps:

1. Calculate the vega risk for each instrument to different risk factors using the formula:

   $$VR_{i,k} = \sum_j \sigma_{k,j} \frac{dV_i}{d\sigma}$$

   where $\sigma_{k,j}$ is the implied at-the-money volatility of the risk factor k at each vol-tenor for Interest Rate and Credit instruments. For other product classes, the volatility can be calculated by :

   $$\sigma_{k,j} = \frac{RW_k \sqrt{365/14}}{\alpha}$$

   where $\alpha = \Phi^{-1}(99\%)$. RW_k is the corresponding delta risk weight mentioned before and the "vol-tenor" j is the option expiry time.

2. Find the net vega risk exposure across instruments to each risk factors. For Interest Rate vega risk, the net vega can be calculated by:

$$VR_k = VRW\left(\sum_i VR_{i,k}\right)VCR_b$$

where $VCR_b = \max\left(1, \left(\frac{|\sum_{i,k} VR_{i,k}|}{VT_b}\right)^{\frac{1}{2}}\right)$. VRW is the vega risk weight for the related risk class. VCR is the vega concentration risk factor. Similarly to the delta margin calculation, VR_k takes into account the concentration risk based on the vega concentration threshold which can be found in Appendix.

3. Aggregate the vega risk exposure within each bucket. The vega risk exposure for each bucket can be calculated as:

$$K_b = \sqrt{\sum_k VR_k^2 + \sum_k \sum_{l \neq k} \rho_{k,l} f_{k,l} VR_k VR_l} \tag{6}$$

where the inner correlation adjustment factor $f_{k,l}$ is 1 for Interest Rate risk class and for other risk classes can be calculated by:

$$f_{k,l} = \frac{\min(VCR_k, VCR_l)}{\max(VCR_k, VCR_l)}$$

Diversification benefits are captured from equation 6, albeit on a vega level.

4. Aggregate the vega risk exposure across buckets within each risk class:

$$VegaMargin = \sqrt{\sum_b K_b^2 + \sum_b \sum_{c \neq b} \gamma_{b,c} g_{b,c} S_b S_c} + K_{residual}$$

where $S_b = \max\left(\min\left(\sum_{k=1}^{K} VR_k, K_b\right) - K_b\right)$. The outer correlation adjustment factors $g_{b,c}$ are 1 for all risk classes other than Interest Rate risk class. $g_{b,c}$ is defined as:

$$g_{b,c} = \frac{\min(VCR_b, VCR_c)}{\max(VCR_b, VCR_c)}$$

Similarly, we can calculate the curvature margin and the procedure for doing so is set out in the ISDA SIMM document.

3.6.7 Initial Margin and Collateral Haircuts

The ISDA SIMM committee has proposed that SIMM should be considered for collateral haircuts. The rationale for this is that the value of the collateral might be correlated to the event of default, and according to the regulators, such an event should be avoided. A proposed solution to the above would be the posting of highly liquid and safe assets such as short-term treasury bills or cash. However, due to the fact that IM cannot be re-hypothecated this might have a negative impact on market liquidity of the above instruments. Consequently, the WGMR has expanded the range of eligible collateral to gold, equities, and high-quality corporate bonds, among others. In order to account for the increased riskiness of these new forms of collateral, ISDA has published a table of haircuts which depend on the underlying collateral, as well as the currency in which it has been posted [28].

4 Implementation and Results

4.1 Timeframe of Analysis

We divide our analysis into three time periods, in order to make meaningful comparisons:

- **Pre-crisis:** This covers the period January 2004 to December 2006. This consists of 773 10-day periods. These are rolling window periods.
- **Crisis Period:** This covers the period January 2007 to December 2009.This consists of 775 10-day periods.
- **Post-Crisis:** This covers the period January 2010 to December 2012 This consists of 773 10-day periods.

Following the financial crisis, rates globally declined as central bankers sought to stimulate their economies. As a result, other rates in the market such as swap rates were also reduced. Figure 7 shows the evolution of the five-year and ten-year swap rates, and a significant drop in interest rates can be seen following the events of September 2008. Products in a typical portfolio following the GFC would have dramatically different strike rates compared to before the crisis. Furthermore, the SIMM model utilizes implied volatility as an indicator of the amount of IM to be posted. Thus dividing the time-frame into sub-periods, will make our comparisons more meaningful as the implied volatilities pre-crisis were radically different from the implied volatilities during 2007-2008 period.

4.2 Portfolio Composition

In our implementation of the SIMM Model, we restrict our focus to one product class i.e. Interest Rates. According to the BIS Semiannual OTC Derivatives Statistics Survey, at the end of 2016 approximately 76% of the OTC market was made up of Interest Rate products with a notional outstanding of around $ 368 trillion [3]. Furthermore, the majority of non-centrally cleared derivatives (which the SIMM model focuses on) are Interest Rate Derivatives. Interest Rate instruments such as caps, floors, and swaptions have embedded optionality in them making them good choices to highlight features of the SIMM model such as vega and curvature margin. The pricing of these products are also relatively simple to compute and are not computationally burdensome. We restrict our focus to USD and EUR denominated instruments as these are among the most liquid and actively traded products.

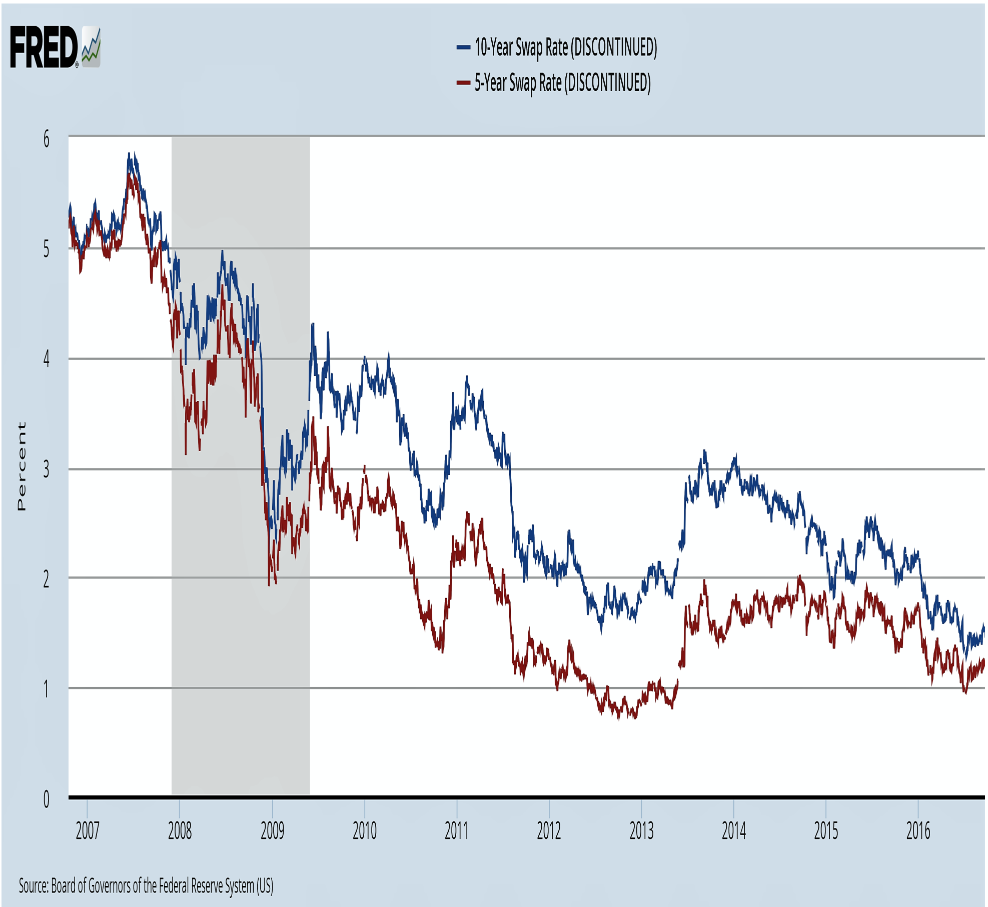

Figure 7: Evolution of 10-year and 5-year mid-market par swap rates. Rates are for a Fixed Rate Payer in return for receiving three month LIBOR, and are based on rates collected at 11:00 a.m. Eastern time by Garban Intercapital plc and published on Reuters Page. The highlighted portion shows the periods leading up to and following the GFC. Source: St. Louis Fed.

We begin by building multiple representative portfolios of interest rate products consisting solely of swaps[10], caps, and floors, as well as swaptions. Following this, we extend our analysis to a larger portfolio consisting of all the products together. The strike levels were chosen to best reflect the prevailing strikes of at-the-money (ATM) options during the period preceding the financial crisis.

Table 1 shows the composition of the portfolios according to the different periods under consideration as well as their underlying tenors, maturities, and relevant currencies.

Interest Rate Products. Notional USD 1M			
Product	Underlying	Maturity	Strike/Fixed Rate
Swap (Receive Fixed)	3m LIBOR	10 years	4.0%
Swap (Pay Fixed)	3m LIBOR	5 years	3.5%
Swap (Receive Fixed)	3m LIBOR	12 years	4.0%
Cap	3m LIBOR	5 years	5.0%
Cap	6m LIBOR	6 years	5.3%
Cap	6m LIBOR	10 years	5.0%
Cap	3m EURIBOR	7 years	4.1%
Cap	6m EURIBOR	3 years	4.2%
Floor	3m LIBOR	3 years	4.8%
Floor	6m EURIBOR	4 years	2.2%
Floor	6m EURIBOR	5 years	2.5%
Payer Swaption (Call)	3m LIBOR	1Y6Y	6%
Payer Swaption (Put)	3m LIBOR	3Y8Y	4.5%

Table 1: Interest rate products that constitute the portfolio for the three periods under consideration.

4.3 Discount and Projection curves

Historically, market participants used a single standard curve (for instance LIBOR 3M) to value their derivative positions. This was based on the notion that all market participants had equal credit risk and could fund themselves at this single rate, and that the credit risk for rates of different maturities was negligible. This notion

[10] Although the SIMM Model has been designed for non-cleared derivatives, we have included an analysis of a portfolio consisting of Interest Rate Swaps only to better understand which features of this model are driving the final IM values.

was invalidated during 2007-2008 when the spread between LIBOR and 'risk-free' Overnight Indexed Swap (OIS) rates such as those based on the Fed Funds rate widened considerably. Figure 8 shows the spread between the USD 3M LIBOR and the Fed Funds Effective Rate for the period December 2006 to January 2017. Prior to the crisis this was approximately 40 bps, but following the collapse of Lehman shot up as high as 400 bps, reflecting the heightened credit risk in the market and unwillingness of market participants to lend to one another.

Following the GFC, market participants started to move away from the use of a single curve for both discounting and forecasting of cash flows. Instead, financial institutions such as banks moved to the use of multiple curves in valuation. Curves for forecasting are still based on LIBOR, but are tailored specifically for different maturities and tenors. Also, many participants construct their discount curves based on overnight indexed swaps such as the Fed Funds rate, Euro OverNight Index Average (EONIA), or Sterling OverNight Index Average (SONIA).

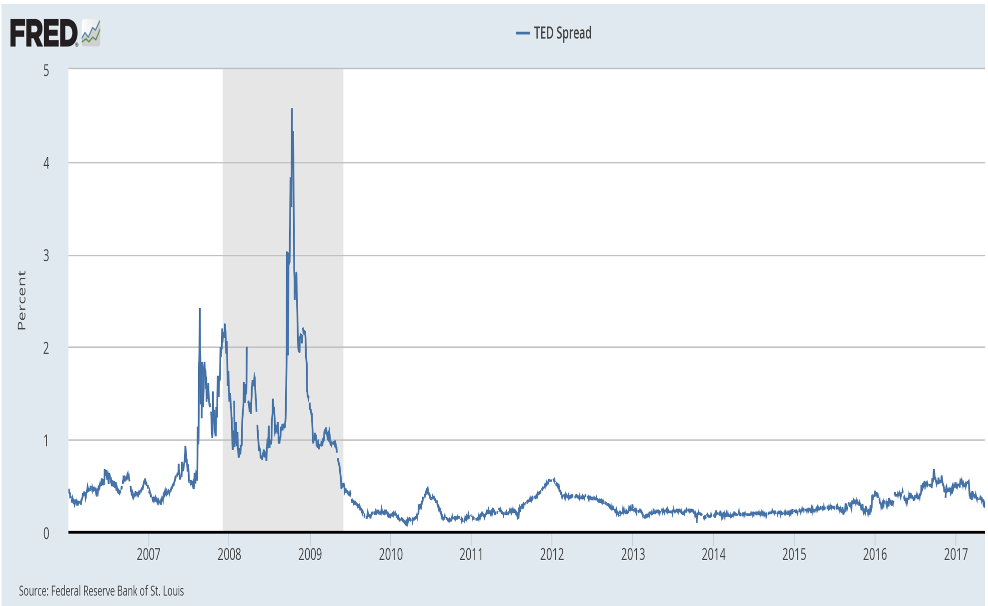

Figure 8: Daily spread between the 3M USD LIBOR and the Fed Funds Rate for the period December 2006 to January 2017. The shaded region represents the period of the Global Financial Crisis.

4.3.1 The Discount Curve

The discount curve is a graphical representation of discount factors for each point in time from today t_0 into the future t_i where $i > 0$. The discount factor is the value of one unit of currency at a future point in time t_i, relative to its value today and is used to discount future cash-flows in the pricing of derivative securities. For example, if the euro one-year interest rate is 1%, the value of EUR 1.0 in one year is approximately EUR 0.99 today.

Following the crisis, there has been increasing pressure for derivative positions to be collateralized. The valuation of the derivative instrument when discounting should be similar to the amount of interest that is earned on the collateral and the margin account. The rate used is a standard overnight rate, such as the Fed Funds, EONIA, or SONIA. These rates are considered as close to risk free as possible since the rates exist only for a single day. There is considerable debate on the role of what curve represents the discount curve. Some participants contend that only collateralized trades should be discounted using the OIS Curve, while trades which are not collateralized should be discounted at the cost of funding for the particular participant.

4.3.2 The Projection Curve

In order to obtain the price today of an instrument such a floating-fixed vanilla swap, it is necessary to present value all the cash flows (both on the floating leg and fixed leg). Forward rates are an estimation of future interest rates, given current market conditions. With floating cash flows, actual values are unknown as they are stochastic. A forward curve must, therefore, be used to estimate the future floating rate and associated cash flows. For example, if the floating leg of the swap is based on 3M LIBOR, then this curve can be used to estimate these future cash flows[11]. The curve that is used to forecast this future cash flows is referred to as the projection curve. Like the discount curve, there are numerous forecast curves (such as 3M and 6M LIBOR with an associated spread between them [12]) and it is important for participants to use the correct forecast curve when forecasting forward rates.

For our analysis the below sub-yield curves have been used: 3M LIBOR, 6M LIBOR, USD OIS, EUR OIS, 3M EURIBOR and 6M EURIBOR. Data has been provided by Bloomberg.

[11] This can be done as long as it is consistent with the structure of the OIS Curve.

[12] Prior to the crisis the spread between different floating curves was relatively small, but this widened during the crisis.

4.4 Additional Assumptions

The following additional assumptions were made in our construction and implementation of the SIMM Model:

- For the calculation of swaptions, we assume that the projection as well as the discount curves discussed in Section 4.3 are the same, thus ignoring the role of credit risk. Since the correlation between different sub-curves is set at 98.2% by ISDA, this approximation does not materially affect the results.
- In the execution of the historical simulation, due to a lack of data for some maturities, there exist NaN fields in the resulting Matlab matrices. In such cases, we use linear interpolation to obtain the missing data. In cases where linear interpolation is not feasible, we take an average of the relevant variables.
- Due to the lack of data for some products, such as swaptions, we could not cover all the interest rate risk factors, as most markets swap rates start from 1 year. We do not include the risk factors such as 2 weeks, 1 month, and 3 months and set the risk for these maturity buckets to zero.
- In order to calculate the sensitivity of the underlying instruments to each of the risk factors we used the Matlab Financial Instruments Toolbox. The prices of caps, floors and swaptions were calculated by the Black Option Pricing model. The corresponding Matlab functions are capbyblk.m, floorbyblk.m, and swaptionbyblk.m. A Matlab implementation of this project is available on request.
- For the swap component, we assumed quarterly resets. The same is true for swaptions.
- In order to obtain the volatility estimates for the respective products, we extracted the Black Vols from the volatility cubes provided by Bloomberg.

4.5 Historical VaR

In order to meaningfully analyse the results of SIMM model, we will perform a comparison between the IM calculated by this model versus IM obtained using Historical VaR, which has been discussed in section 2.3.2.The Historical VaR procedure involves following steps:

1. A 10-day rolling window is used to obtain the relative 10-day shifts in the relevant zero coupon curves (including the OIS curves) associated with each day in the look-back period;

2. Applying the ten-day curve shifts to the most recent swap curve in order to obtain a set of hypothetical zero-coupon swap curves for T+10;

3. Revalue each swap futures contract under the hypothetical set of curves for T+10, using the discount and projection curves as described above;

4. Calculate the profit and loss (P&L) for each instrument under each hypothetical curve;

5. Aggregate the contract-level P&Ls in order to obtain the portfolio-level P&L associated with each hypothetical curve, and obtain the 99th percentile of the portfolio-level P&L. The rolling window approach is used because a default event can occur on any day(instead of every 10 days) and this also increases the number of data points.

4.6 SIMM Calculation

The SIMM methodology is based on a sensitivity-based model. ISDA has specified a number of risk factors [13] and the amount of IM required by the SIMM model is highly dependant on the sensitivity of the underlying portfolio to these risk factors. The first step of the initial margin calculation involves the calculation of the delta margin, which is a first-order derivative measuring the change in the price of an instrument with respect to a change in the underlying risk factor. ISDA uses the term "sensitivity" to represent this amount and the sensitivity is calculated using the following formula:

$$s = V(x + 1bp) - V(x) \tag{7}$$

[13]The risk factors chosen by ISDA for the Interest Rate class are the 12 yields at the following vertices, for each currency: two weeks, 1 month, 3 months, 6 months, 1 year, 2 years, 3 years, 5 years, 10 years, 15 years, 20 years and 30 years.

For each risk factor, we shock the target rate by 1 bp, keeping other rates constant. The curve is then rebuilt and the instrument under consideration is repriced according to this new 'bumped' curve. For example, consider the case of a 5 year floating-fixed swap whose corresponding sub-yield curve is the 3-month USD LIBOR curve. We begin by shocking the two week vertex which represents the first risk factor of this particular yield curve. The instrument is revalued using the new 'shocked' curve, and the difference between the new value and the old value represents the delta sensitivity for the two-week risk bucket. This is done for the remaining 11 risk factors which have been identified by ISDA.

The sensitivities calculated above need to be risk-weighted according to their tenors as well as a factor that takes into consideration how concentrated the portfolio is. The resulting amount represents a weighted sensitivity measure.

$$WS_{m,i} = RW_m * s_{m,i} * CR_b$$

where the RW_m is the risk weight predefined by ISDA and is classified according to the currency of each sub-yield curve. CR_b is a concentration risk factor, which can be calculated as:

$$CR_b = \max\left(1, \left(\frac{|\sum_{m,i} s_{m,i}|}{T_b}\right)^{\frac{1}{2}}\right) \tag{8}$$

The parameter values for RW_m and CR_b can be found in Appendices B.1 and B.3. For the example given above, if the sensitivity of the 5 year swap in the 2 week risk bucket was USD 10,000, then the weighted sensitivity would be USD 7,700 based on a risk-weight off 77% to the two week vertex (for regular currencies such as USD), and a concentration threshold of 1 (since the ratio of the net sensitivity of our one product portfolio does not exceed the notional threshold of 250 USD mm/bp).

$$WS_{2\_week\_risk\_tenor,5year\_swap} = 0.77 * 10,000 * 1$$

Once all the weighted sensitivities in the respective risk buckets are obtained for a particular currency, they can be aggregated by Equation 9 which uses a variance-covariance-like calculation to account for any diversification benefits across different maturity buckets within a currency. In order to take diversification benefits across currencies into account, Equation 10 is used.

$$K = \sqrt{\sum_{i,m} WS_{m,i}^2 + \sum_{i,m} \sum_{(j,n)\neq(i,m)} \phi_{i,j}\rho_{m,n} WS_{m,i} WS_{n,j}} \tag{9}$$

$$DeltaMargin = \sqrt{\sum_b K_b^2 + \sum_b \sum_{c \neq b} \gamma_{bc} g_{bc} S_b S_c} \tag{10}$$

where,

$$S_b = \max(\min(\sum_{i,m} WS_{m,i}, K_b), -K_b)$$
$$g_{bc} = \frac{\min(CR_b, CR_c)}{\max(CR_b, CR_c)}$$
$$\gamma_{b,c} = 27\%$$

Similarly, the vega and curvature margins are calculated as described in section 3.6.6 first on a currency level, and then these amounts can be aggregated across currencies to realize diversification benefits. Finally, the overall IM for our portfolio is given by the equation below which is the sum of the delta, vega and curvature margins:

$$IM_X = DeltaMargin_X + VegaMargin_X + CurvatureMargin_X \tag{11}$$

.

The reason for incorporating the higher level derivatives such as Vega and Curvature Margins is due to the fact that delta margin alone cannot explain well enough the change in the value of a portfolio, especially for products that have optionality embedded into them such as swaptions and caps and floors. Furthermore, the effect of volatility on the prices of derivative instruments is not negligible and therefore an estimate to take into account the impact of volatility is necessary. With regards to curvature margin, O'Kane contends that [19] for products that do have a curvature risk, this captures the cross term between the vega and gamma of the option.

In the original SIMM Model, the IM obtained for each product class is then used as an input into a equation similar to Equation 9 but on a product class level. However, since we restrict our focus to the interest rate class only, we can ignore any cross-terms and correlations with the other product classes such as Credit and Equity. The final IM is given by equation 11.

4.7 Analysis

In order to arrive at the P&L, we priced up the representative portfolio using 10-day period intervals and calculate the difference between successive periods, keeping the portfolio composition constant throughout as described above in section 4.5.

According to the Historical VaR approach, the IM required is the 10-day 99% upper-tail VaR. At first, we conduct a separate analysis by considering the SIMM on a product-specific level (for instance, caps and floors). The results are explored in subsections 4.7.1,4.7.2 and 4.7.3. Section 4.7.4 then considers the overall portfolio which is a combination of the above two sub-portfolios allowing us to examine any diversification effects. For the SIMM component, the IM is calculated on a single day for each of the 3-year periods i.e. pre, during and post-crisis and this takes place on the last day of the period.

4.7.1 Swaps

Analyzing the case of a swaps-only portfolio allows us to examine the SIMM Model in more detail as vanilla swaps are fairly linear, as they have no embedded optionality (and hence no vega and curvature risk). Table 2 illustrates the comparisons between the Historical VaR amount and the amount of IM required by SIMM. Any amount of IM for the SIMM purely comes from the delta contribution, and the amount of IM required by both methodologies are higher during the GFC. In periods of relative stability, the Historical VaR approach exceeds the SIMM model, due to the fat-tailed nature of asset returns which can be seen in Figure 9.

During the GFC, the SIMM requires more margin compared to the Historical VaR illustrating that the model is capable of providing better protection against possible default events. One disadvantage of this feature is that higher amounts of capital are tied up in the form of collateral which might impact liquidity at a time when a market participant might need access to it the most.

	Historical VaR	**SIMM**	**Delta**	**Vega**	**Curvature**
Pre-Crisis	40,791.68	28,136.01	28,136.01	0	0
GFC	111,783.80	141,904.50	141,904.50	0	0
Post-Crisis	71,722.34	33,954.48	33,954.48	0	0

Table 2: Comparison between SIMM and Historical VaR Approach in USD for Portfolio of Swaps. The IM for the Delta, Vega and Curvature margins for the SIMM Model have also been included.

Looking at a portfolio of swaps incrementally also enables to observe how the interaction and diversification effects of the SIMM Model come into play. The SIMM Model requires an initial margin of USD 27,818 for Swap 1 pre-crisis, and USD

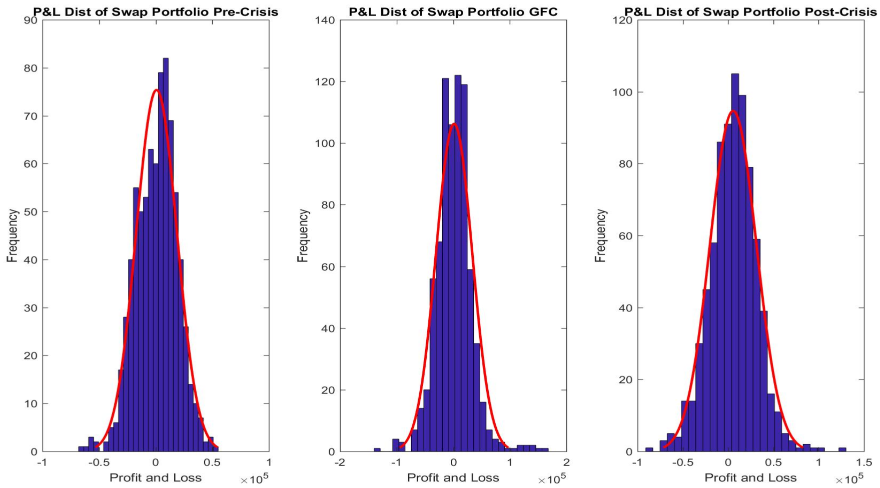

Figure 9: Distribution of PnL values for different time periods for a simple portfolio consisting of Interest Rate Swaps.

14,572 for Swap 2 during the same period as shown in Table 3. Since Swap 1 is a Receive Fixed swap and Swap 2 is a Pay Fixed Swap, we should expect some netting effects. Indeed, the SIMM model requires the posting of IM of 28,818 for Swaps 1 and 2 in combination, illustrating that diversification effects across maturities and netting effects across products within risk classes are taken into account.

	Swap 1	Swap 2	Swap3	Swap 1 and 2	Swap 1 and 3
Pre-Crisis	27,818.24	14,572.90	2,465.18	28,818.37	27,401.43
GFC	30,832.27	78,538.94	234,415.82	98,955.55	217,628.38
Post-Crisis	38,742.77	24,626.33	4,504.907	33,664.45	37,595.56

Table 3: Table showing the IM in USD for individual swaps and combinations of swaps.

4.7.2 Cap and Floor Portfolios

Figure 10 shows the distribution of the historical P&L for each of the sub-periods for a portfolio consisting of caps and floors. Table 4 displays the comparisons between the Historical VaR approach and SIMM approach as well as a breakdown of the individual components. Due to the presence of optionality in caps and floors, we find that the vega and curvature values are non-zero. We also find that for caps and floors that the IM remained more-or-less the same for all time periods. This highlights the non-cyclicality property of the SIMM Model.

The majority of IM comes from the delta component, with the vega and curvature contributing little to the overall margin, and with vega margin always exceeding curvature margin. The vega and curvature amounts during the GFC were significantly higher in magnitude compared to the prior and following periods reflecting the volatility of this period.

Table 5 shows the netting effects between different risk tenors. Cap 4 is based on 3m EURIBOR, and Cap 5 on 6m EURIBOR. A portfolio consisting of both products requires an IM that is less than the sum of the initial margins of each product in isolation. Similarly, Table 6 shows the netting effects between cap 4 and floor 5, illustrating netting across products within the same risk class.

	Historical VaR	**SIMM**	**Delta**	**Vega**	**Curvature**
Pre-Crisis	30,939.49	29,024.64	28,790.98	168.27	65.42
GFC	51,481.57	28,897.00	28,192.50	495.87	208.63
Post-Crisis	13,912.14	27,677.99	27,383.71	237.49	56.79

Table 4: Comparison between SIMM and Historical VaR Approach in USD for Portfolio of Caps and Floors. The IM for the Delta, Vega and Curvature margins for the SIMM Model have also been included.

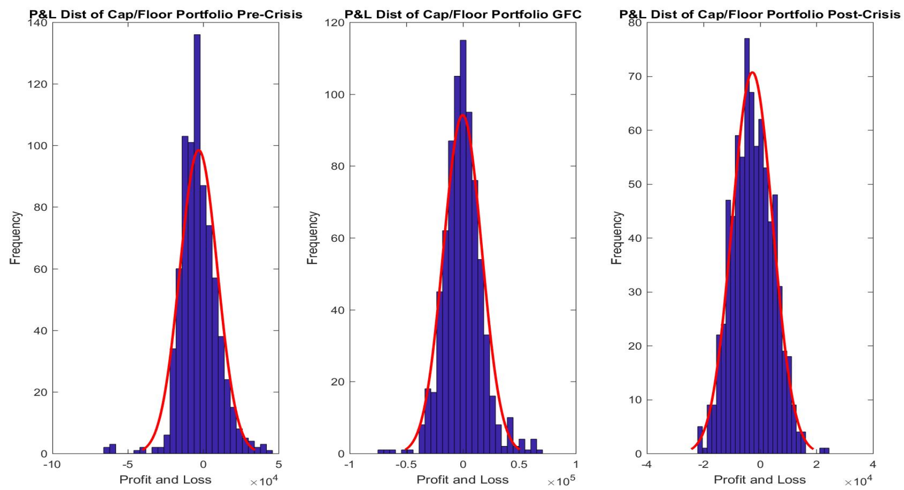

Figure 10: Distribution of PnL values for different time periods for a simple portfolio consisting of Interest Rate Caps and Floors.

	Cap 4	**Cap 5**	**Cap 4 and Cap 5**
Pre-Crisis	3 388.16	7 190.55	6 538.50
GFC	1 685.12	6 594.05	6 318.75

Table 5: Table showing the IM in USD for individual caps and combinations of caps.

	Cap 5	**Floor 3**	**Cap 5 and Floor 3**
Pre-Crisis	7 190.55	2 121.95	6 879.88

Table 6: Table showing the IM in USD for an individual cap and floor and a combination of the two.

4.7.3 Swaption Portfolio

Figure 12 shows the distribution of the historical P&L for each of the sub-periods for a portfolio consisting of swaptions. Table 7 illustrates the comparisons between the Historical VaR approach and the SIMM approach showing the breakdown of the individual components. Notice that the SIMM initial margin is extremely close to Historical VaR during the GFC. This is a reassuring feature of the model in that in periods of financial stress,the margin can cover large losses while freeing up capital for other purposes in periods of relative calm.

A puzzling feature of the SIMM is that following the crisis the model produces an IM for the delta margin that exceeds the margin required during the crisis period. We contend that this due to the calculation methodology of the SIMM model, as it is highly dependent on the dates of the calculation and sensitive to the prevailing rates and volatility environment when the implied volatilities and interest rates during this period were significantly lower than during the preceding years. Figure 11 illustrates the reduction in volatility and rates towards the end of 2009.

	Historical VaR	**SIMM**	**Delta**	**Vega**	**Curvature**
Pre-Crisis	8 203,87	1 442,32	1 349,37	62,83	30,12
GFC	38 250,80	38 984,81	38 767,60	124,93	56,28
Post-Crisis	27 763,59	68 566,96	68 488,74	59,53	18,69

Table 7: Comparison between SIMM and Historical VaR Approach in USD for Portfolio of Swaptions. The IM for the Delta, Vega and Curvature margins for the SIMM Model have also been included.

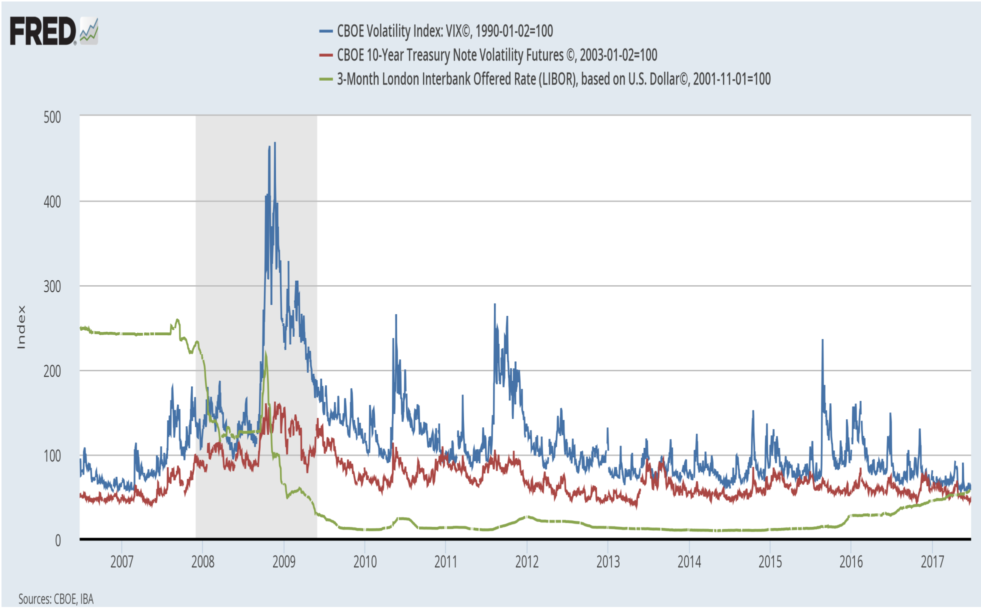

Figure 11: Graph depicting the evolution of the CBOE Volatility Index (VIX), the CBOE 10-year Treasury Note Volatility Futures Index and the 3-Month USD LIBOR Rate. The graphs have been re-based at the level of 100, with the rebase dates indicated on the legend. The highlighted region depicts the period of the GFC during which significant upward spikes were observed in the VIX and Treasury Note Volatility Index , and a large reduction in short-term rates represented by the 3M Libor rate.

4.7.4 Overall Portfolio

Figures 13 ,14 and 15 show the distribution of the historical P&L for each of the sub-periods for the overall portfolio which is made up of the individual products discussed in the preceding sections. These distributions are Gaussian-like with a slight left skew. Table 8 compares the historical VaR with the initial margin calculated by the SIMM model illustrating the delta, vega and curvature components.

	Historical VaR	**SIMM**	**Delta**	**Vega**	**Curvature**
Pre-Crisis	45 949,53	35 191,19	34 877,04	221,08	93,07
GFC	126 772,76	188 896,89	188 043,57	593,384	259,93
Post-Crisis	111 456,84	83 098,22	82 747,49	278,35	72,38

Table 8: Comparison between SIMM and Historical VaR Approach for the overall portfolio in USD. The IM for the Delta, Vega and Curvature margins for the SIMM Model have also been included.

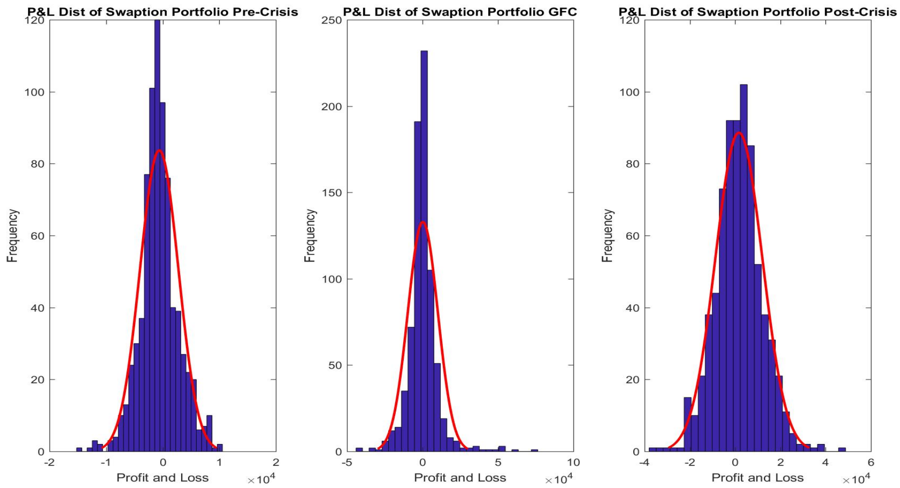

Figure 12: Distribution of PnL values for different time periods for a simple portfolio consisting of Interest Rate Swaptions.

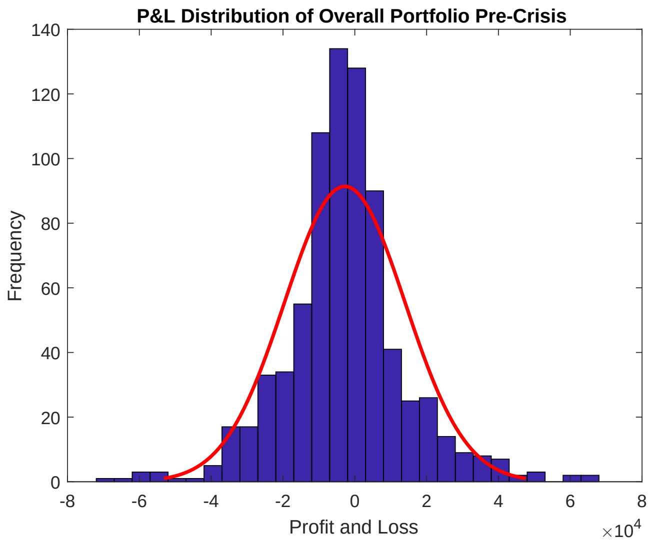

Figure 13: Distribution of PnL Values Pre-Crisis for the Overall Portfolio.

According to Table 8, during the GFC, both models lead to greater amounts of margin due to unstable market conditions. However, the amount of IM required by SIMM exceeds the Historical VaR amount. We can conclude from this that ISDA's aim is to ensure that in periods of market turmoil more initial margin needs to be posted to maintain the stability of the financial system and prevent contagion effects.

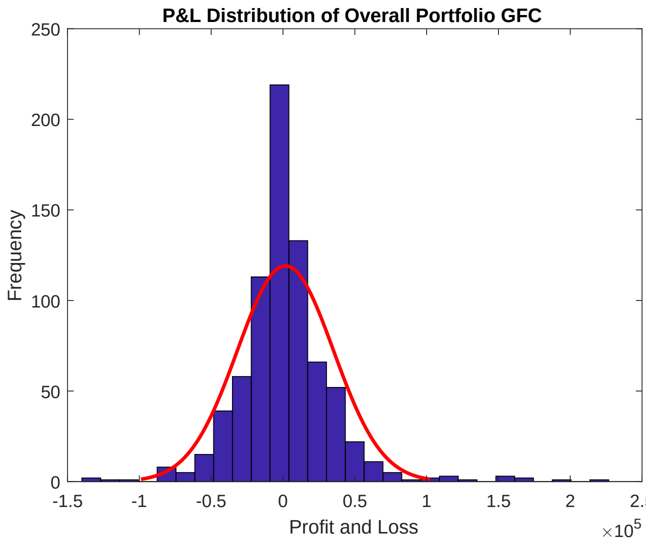

Figure 14: Distribution of PnL Values during the Crisis for the Overall Portfolio.

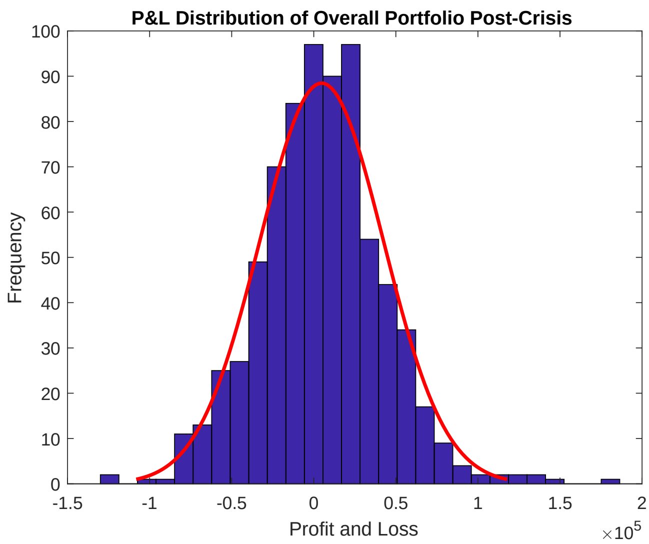

Figure 15: Distribution of PnL Values Post-Crisis for the Overall Portfolio.

Before and after the crisis, the Historical VaR exceeds the value of the SIMM model which we expect due to the fat-tailed nature of asset returns. Moreover, the 99% Historical VaR can be considered an overly conservative measure. During normal market periods, when volatility is relatively low, the SIMM model avoids the posting of extraneous collateral, taking into account that excessive margins lead to potential liquidity issues. It is also worth mentioning that the difference between the two models will be dependent upon the time-period under consideration. For the interest rate product class, the model inputs are the rates as well as the implied volatilities. Since implied volatility is a forward-looking measure, it gives an indication of expectations for future market volatility. Furthermore, the IM stipulated by the SIMM model was more than able to cover any actual losses that would have been incurred by our hypothetical portfolio.

An interesting observation to note is that in the overall portfolio, the effect of diversification becomes clear with the overall SIMM margin in each period being much less than the individual sum of margins of each product. Our portfolio consists of long positions only, and the inclusion of short positions would decrease the netting set and lead to even more benefits. This is one of the advantages of the SIMM model in that allows netting within a product class and allows for the realization of diversification benefits. The impact of low interest rates and volatility post-2009 carries through to the overall portfolio with the higher vega and curvature margins observed post-crisis than during the crisis. Very little diversification occurs on the vega level with the IM resulting from vega being slightly less than what would be obtained from a simple addition of the respective vega margins for the products making up the portfolio. Diversification dominates on the delta level.

The standardized approach (NIM) produces an IM of USD 400,000 [14] during all time periods. Therefore, the SIMM model is the least conservative of all three in 'normal' markets, suggesting that it takes into account the correlation effects between various maturities as well as any offsets, while being conservative in periods of market turmoil. This is an important feature which satisfies the criteria of Margin Appropriateness as discussed in sub-section 3.2.

4.8 Criticisms of the model

One of the requirements for the SIMM model is that any IM posted will need to be segregated and cannot be re-hypothecated. This has an impact on total market liquidity and a model which is extremely conservative would lead to institutions posting higher amounts of collateral as IM, thus reducing overall liquidity in the market, especially in periods of turmoil. Furthermore, as the SIMM is based on a sensitivity based approach (SBA), different models will produce different sensitivities. Calculating sensitivities for some exotic instruments can be complicated and time-consuming for certain products.

Although the model is fairly quick and easy to replicate, this is dependent upon both counterparties using the same valuation methodologies. Despite ISDA's recommendation that any IM model should be transparent, we argue that the document provided did not elaborate on the rationale behind the choices of the risk factors, as well as the calculation of sensitivities. The SIMM model assumes the sensitivities are given. The table of correlations provided by ISDA remain opaque and have to be continuously updated and transferred to market participants.

The frequency at which this is done is arbitrary and has not been specified thus making the market reliant on ISDA to provide the necessary calibration of the model. It is worth bearing in mind that the SIMM is just a model, consisting of simple assumptions (it is based on Gaussian distribution), has low granularity, and does not cover all risk classes such as dividend risk and skew risk. The model should be an evolving one and continuously be subject to reforms and improvements. An industry-wide effort will be needed in order to provide back-testing, and all stakeholders need to provide feedbacks in order to make the model an efficient mechanism

[14] Our portfolio consists of thirteen products each with a notional of USD 1M. Six of these products have a maturity bucket of between 2-5 years (with a corresponding risk weight of 2%) and the remainder have a maturity exceeding 5 years with a risk weight of 4%. The NIM is therefore: ((6m*2%)+(7m*4%)). Since there are only long positions in this portfolio, no netting benefits are realized and the NIM is the same as the Gross Initial Margin.

to reduce systemic risk.

An advantage of the SIMM model is that it is quite sensitive to market data, allowing inputs such as the volatility and the rate environment to play a role in margin calculations, making the overall SIMM model more responsive to changing conditions. The flip-side to this is that abnormal market conditions on a single day can lead to unreasonable margins. While the model is sensitive to market inputs, the SIMM model utilizes a static correlation framework which may not be sensitive to changes in market conditions.

5 Conclusion

This paper provides an overview of the new SIMM model which came into effect September 2016. We analyse this model and look at whether it satisfied the criteria stipulated by the WGMR. We find that although the resulting IM is less conservative than traditional methods such as Historical VaR and the NIM method, it nonetheless was able to cover any actual losses that would have been incurred by a hypothetical portfolio during the financial crisis. This is a promising feature as it would not have a large impact on market liquidity for collateral. Furthermore, this margin model takes into account diversification effects between different risk factors. It also captures various risk sensitivities, recognizing that certain product classes are riskier than others. The model is easy to implement as well as margin appropriate meaning that larger portfolios do not lead to large overstatements of risk.

A drawback of the model is that the correlation parameters are static in nature, and very little guidelines have been provided by ISDA regarding how these correlations have been calculated. Like any model, the SIMM framework has drawbacks and cannot guarantee that losses beyond the calculated IM will not be realized, but we believe that the SIMM methodology is a stepping stone towards the more efficient management of risk and ensuring a coherent, market-wide initiative. Further and continuous back-testing will provide indicators as to whether the SIMM model is a feasible one and as the model begins to be adopted by market participants room for possible improvements will emerge.

Future studies can look at incorporating more product classes, both long and short positions as well as more elaborate products. Another focus area could be analysing any correlation effects between the collateral posted and the underlying asset of the portfolio. Additionally, the current SIMM model does not allow for netting across product classes which leads to higher margin requirements. The appropriateness of this can be tested by comparing this to the case where netting is allowed to see if there are any material differences. Ultimately, the trade-off between any IM model should balance the need for maintaining liquidity in the market by avoiding the posting of too much collateral, but at the same time ensuring that should a period of financial distress materialize then any IM posted will be more or less sufficient to cover any losses and prevent a systematic crisis or contagion in the market.

Appendices

A

Table of Add-ons for the Schedule Based Approach

Asset Class	**IM (% of Notional**
Credit (0 -2 years)	2%
Credit (2 -5 years)	5%
Credit 5+ years	10%
Commodity	15%
Foreign Exchange	6%
Interest Rate (0 -2 years)	1%
Interest Rate (2 -5 years)	2%
Interest Rate 5+ years	4%
Other	15%

Table 9: Scheduled Based Approach: IM is a certain percentage of margin

B Interest Rate Product Class parameters

B.1 Risk Weights

The set of risk-free yield curves within each currency is considered to be a separate bucket. The risk weights W_k are set out in the following tables:

- There is one table for regular volatility currencies, which are defined to be: the US Dollar (USD), Euro (EUR), British Pound (GBP), Swiss Franc (CHF), Australian Dollar (AUD), New Zealand Dollar (NZD), Canadian Dollar (CAD), Swedish Krona (SEK), Norwegian Krone (NOK), Danish Krona (DKK), Hong Kong Dollar (HKD), South Korean Won (KRW), Singapore Dollar (SGD), and Taiwanese Dollar (TWD).
- There is a second table for low-volatility currencies, which are defined to be the Japanese Yen (JPY) only.
- There is a third table for high-volatility currencies, which are defined to be all other currencies.

2w	**1m**	**3m**	**6m**	**1yr**	**2yr**	**3yr**	**5yr**	**10yr**	**15yr**	**20yr**	**30yr**
77	77	77	64	58	49	47	47	45	45	48	56

Table 10: Risk weights per vertex (regular currencies)

2w	**1m**	**3m**	**6m**	**1yr**	**2yr**	**3yr**	**5yr**	**10yr**	**15yr**	**20yr**	**30yr**
89	89	89	94	104	99	96	99	87	97	97	98

Table 11: Risk weights per vertex (high-volatility currencies)

2w	**1m**	**3m**	**6m**	**1yr**	**2yr**	**3yr**	**5yr**	**10yr**	**15yr**	**20yr**	**30yr**
10	10	10	10	13	16	18	20	25	22	22	23

Table 12: Risk weights per vertex (low-volatility currencies)

B.2 Table of Correlations

	2w	1m	3m	6m	1yr	2yr	3yr	5yr	10yr	15yr	20yr	30yr
2w	1	1	1	0.782	0.618	0.498	0.438	0.361	0.27	0.196	0.174	0.129
1m	1	1	1	0.782	0.618	0.498	0.438	0.361	0.27	0.196	0.174	0.129
3m	1	1	1	0.782	0.618	0.498	0.438	0.361	0.27	0.196	0.174	0.129
6m	0.782	0.782	0.782	1	0.84	0.739	0.667	0.569	0.444	0.375	0.349	0.296
1yr	0.618	0.618	0.618	0.84	1	0.917	0.859	0.757	0.626	0.555	0.526	0.471
2yr	0.498	0.498	0.498	0.739	0.917	1	0.976	0.895	0.749	0.69	0.66	0.602
3yr	0.438	0.438	0.438	0.667	0.859	0.976	1	0.958	0.831	0.779	0.746	0.69
5yr	0.361	0.361	0.361	0.569	0.757	0.895	0.958	1	0.925	0.893	0.859	0.812
10yr	0.27	0.27	0.27	0.444	0.626	0.749	0.831	0.925	1	0.98	0.961	0.931
15yr	0.196	0.196	0.196	0.375	0.555	0.69	0.779	0.893	0.98	1	0.989	0.97
20yr	0.174	0.174	0.174	0.349	0.526	0.66	0.746	0.859	0.961	0.989	1	0.988
30yr	0.129	0.129	0.129	0.296	0.471	0.602	0.69	0.812	0.931	0.970	0.988	1

Table 13: Correlation values for different maturities.

For sub-curves, the correlation $\phi_{i,j}$ between any two sub-curves of the same currency is 98.2%. The parameter $\gamma_{b,c} = 27\%$ should be used for aggregating across different currencies and The vega risk weight, VRW, for the Interest Rate risk class is 0.21.

B.3 Concentration Thresholds

The delta concentration thresholds for interest rate risk are classified by currency groups:

Currency Risk Group	**Concentration threshold (USD mm/bp)**
High volatility	7.4
Regular volatility, well-traded	250
Regular volatility, less well-traded	25
Low volatility	17

Table 14: Delta concentration threshold for Interest Rate products

The currency risk groups used in establishing concentration thresholds for Interest Rate Risk are as follows:

- High volatility: All other currencies
- Regular volatility, well-traded: USD; EUR; GBP
- Regular volatility, less well-traded: AUD; CAD; CHF; DKK; HKD; KRW; NOK; NZD; SEK; SGD TWD
- Low volatility: JPY

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