Validation of CFM

A validation of the Margin Model CFM for interest rate products used by Nasdaq OMX

December 2014

Revision history:

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2014-11-18	1.0	Initial draft	Bengt Jansson
2014-12-01	1.1	Draft	Bengt Jansson
2014-12-03	1.2	Final version	Bengt Jansson
2014-12-09	1.3	Adjusted for comments	Bengt Jansson

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1. Background

1.1 General

NASDAQ OMX Clearing AB ("NOMX Clearing") provides clearing and Central Counterparty ("CCP") services. In order to prudently manage these services NOMX Clearing uses a large number of different models. This report is the validation of the margin model Cash Flow Margin model, CFM.

The purpose of a validation of models is to ensure the theoretical and empirical soundness of the models used by the CCP. The validation report should ensure transparency on the models used by the CCP for the benefit of:

- Board of Directors, NASDAQ OMX Clearing AB.
- Competent Authorities
- Internal Audit and Audit Committee
- Other stake holders

1.2 Legal environment

NOMX Clearing was at the 19th of March 2014 authorised as Central Counterpart (CCP) to offer services and activities in the Union in accordance with Regulation (EU) No 648/2012 of the European Parliament and of the Council of 4 July 2012 on OTC derivatives, central counterparties and trade repositories[1].

The legal framework that governs NOMX Clearing is therefore the EMIR framework, Regulation (EU) No 648/2012 and supporting delegated Regulations 148/2013, 149/2013, 150/2013, 151/2013, 152/2013, 153/2013, 285/2014, 667/2014, 876/2013, 1003/2013 and the implementing Regulations 484/2014, 1247/2012, 1249/2012.

The Regulation of particular interest for this validation is Delegated Regulation No 153/2013 "supplementing Regulation (EU) No 648/2012 of the European Parliament and of the Council with regard to regulatory technical standards on requirements for central counterparties".

2. Input to the validation

2.1 Documentation at NOMX Clearing

2.1.1 Previous validation of CFM

In NOMX Clearing's application for being a authorised as a CCP and to offer services and activities in the Union in accordance with Regulation (EU) No 648/2012 a validation of the margin model CFM was amended. This validation will act as an important building block for this new validation. The full document name is: "Validation of CFM model ver 1.0, 2013"

[1] Usually referred to as "EMIR"

2.1.2 Addition to validation of CFM

In the beginning of 2014 an addition to the original CFM model validation was made. This will act as one source of information for this validation. The full document name is: "Addition to validation of the CFM margin methodology final, 2014"

2.1.3 Margin methodology guide for CFM

This guide is in line with NOMX Clearing's standard when it comes to documentation available for the member community. It is meant as a general guide and not necessarily as a technical document describing the actual IT implementation of the model. The full document name is: "Nasdaq OMX Cash Flow Margin (130913)"

2.1.4 CFM Model instruction

This instruction is in line with Nasdaq OMX standard when it comes to documentation available in respect of model calibrations. It is a document generally explaining the theoretical back ground of a margin model. The document name is: "CFM Model Instructions v2 (131001)"

2.1.5 Risk Parameter Methodology

This document describes the specific methodology to calculate risk parameters for the CFM model. The document name is: "CFM - Risk parameter methodology"

2.1.6 Policies

A lot of policies will be included as input to this validation. The following list will name the most prominent policies in this aspect:

- Policy for the Validation of Models: The starting point for the construction, reporting set up and the content of the validation is the policy for validating model that is approved by the Board of Directors at NOMX Clearing. The full document name is: "Model Validation Policy NOMX (140801)"
- Policy for setting risk parameters: NOMX Clearing has developed policies that regulate how risk parameters should be estimated.. The full document name is: "Risk Parameter Policy NOMX (140319)"
- Policy for back testing of models: NOMX Clearing has developed policies that regulate how back testing should be conducted from a theoretical, and very general, point of view. More specific guidelines can be found for specific models. The full document name is: "Back testing Policy NOMX (130513)"
- Policy for stress testing of models: NOMX Clearing has developed policies that regulate how stress testing should be from a theoretical, and very general, point of view. More specific guidelines can be found for specific models. The full document name is: "Stress Test Policy NOMX (140228)"
- Policy for sensitivity testing of models: Nasdaq OMX has developed policies that regulate how sensitivity testing should be from a theoretical, and very general, point of view. More specific guidelines can be found for specific models. The full document name is: "Sensitivity testing and analysis Policy (130909)"

2.2 Numerical analysis of CFM

NOMX Clearing has ongoing numerical procedures as place to deliver numerical output from each margin model that its use. The numerical data can be roughly divided into three separate parts:

- Back testing data
- Stress testing data
- Sensitivity analysis data

2.3 Discussions

In any validation a large part of the information received must be thoroughly discussed with the personal at the CCP. The following persons are however prime sources of information to this model validation:

- Henrik Rosén, Risk Management department of NOMX Clearing
- Karl Klasén, Risk Management department of NOMX Clearing

2.4 Special issues

CFM has been validated (Validation of CFM, NOMX, 2013) in the year 2013 in connection with the application for being a authorised as a CCP and to offer services and activities in the Union in accordance with Regulation (EU) No 648/2012. Since a margin model must, and should, be validated on a yearly basis each validation will be updated with new issues as:

- New added functionality to the margin methodology
- New types of instruments or markets added to the group of instruments and markets in which the margin model is used
- Changed financial environment as different volatility in the market
- New distribution of counterparts as increased risk towards certain firms
- New legislation that changes the rules thereby contradicts assumptions made in the model

The previous validation consists of several documents since additions to the first validation were done (Addition to validation of CFM, NOMX, 2013). This indicates that it will be somewhat challenging to refer back to previous validation.

3. Theoretical framework of the model

3.1 Background on VaR and margin models

3.1.1 Basic VaR methodologies

For a portfolio of investments it is often important to calculate risk measures that try to capture the risk in one separate number. For the past decade the family of risk measures that are most used for this is usually referred to as Value at Risk (“VaR”). VaR tries to state the following:

“With a certain probability *X* there will be no losses for this portfolio exceeding *Y* in the next *N* days”

- Probability: A VaR calculation is made with a confidence level, *X*. In many cases this level is quite high (99%) because it is the losses in the distribution tail that are of interest.
- *N* days: A VaR calculation also needs a time horizon. A longer period will give a higher value compared to a shorter one.
- *Y*: This is the VaR measure.

The basic principle can easily be shown in the Figure 1 below were the tails of the distribution represent the extreme gains and losses of a portfolio.

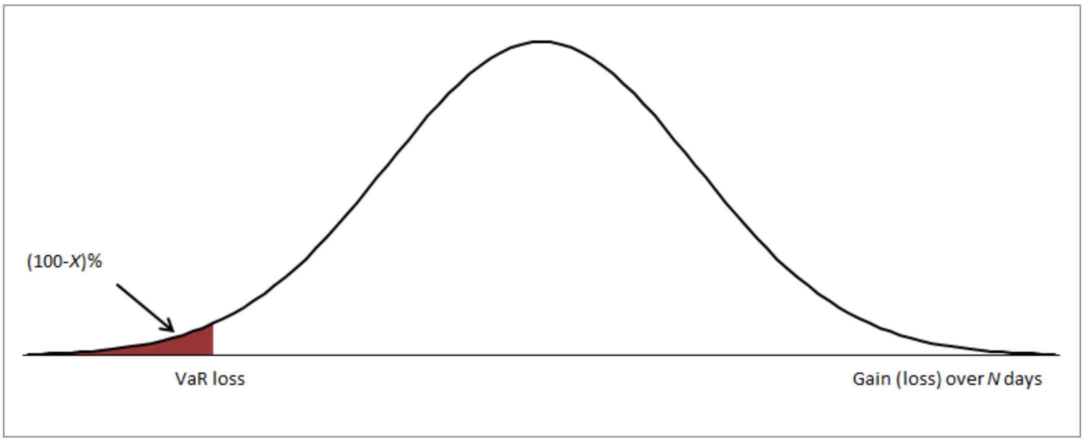

Figure 1: Basic VaR principle

There are a lot of different mathematical methods to calculate a VaR measure, all with different advantages and weaknesses. The main challenges are to estimate the following:

- The volatility of the instruments in the portfolio
- The correlation between the instruments in the portfolio

When these challenges have been solved, or rather when the approximations to use have been decided; the calculations are quite straightforward from a mathematical point of view.

The merits of a VaR model are in its predictability. That means that a model that overestimates the risk is equally bad as a model that underestimates the risk. This implies that different models are suitable for different type of underlying markets (gold, currency, etc.), instruments (derivatives, linear products, etc.) and market states (Low volatile market, high volatile market, crashing market, etc.).

When a VaR model is chosen as a model to use it is prudent to spend some time contemplating what market and state it should be used to provide information on. A model itself can of course be poorly implemented from a mathematical or technical point but the waste majority of problems come from using the model in a non fitting environment.

3.1.2 Basic margin methodologies

Early margin models pre-date VaR models by several decades. This can be seen in many of the architectural decisions that have been done in these models. The pre-conditions for these models included:

- Limited computer power, in some cases the computational force that was necessary to actual perform the calculations were done on the "super computers" of the time.

- Limited research and familiarity of portfolio theory, the introduction of derivatives might not be entirely new but the scale and organization of the trading and clearing certainly was.
- “Keep it simple” was something that was necessary for the margin models to be accepted by the member community. No “black boxes”!

All these pre-conditions lead to some joint features of all the traditional commercially available margin models[2].

- Mainly designed for linear products (futures)
- Step motherly treatment of time dependency for contracts with the same underlying but different expiry.
- Low, or no, correlation between instrument based on different, but correlated, underlying.
- The calculations are very dependent on accurate market prices on exactly those instruments that can be found in the cleared portfolio. No accurate way to use “price factors”. In practice these models depend on settlement prices from a corresponding market place.

It might seem that margin models are very crude, full of drawbacks and of limited value. It is true that the underlying functionality of a traditional margin model is a little bit blunt but it gets the job done! The models are resilient against changes in correlation structure and can easily adopt to high volatility states in the market. They are easy to explain to external parties and easy to predict.

3.2 Basic CFM calculations

3.2.1 VaR or Margin model?

When designing new margin models that are more geared toward OTC clearing it is a natural step that these models get more “VaR” feeling than the traditional margin models. The CFM model lend much of it handling of yield curves from traditional VaR model when it uses the principal components as major risk factors in the model.

This not surprising since the development among clearinghouses has been moving more towards these models because their clients like them and it is generally easier to incorporate new types of instruments in these types of models.

It is important to understand that the features that are the benefit of using VaR models also can be considered a problem when used as margin model. Compensating for correlation structure could lead to under margin when correlation structure shifts.

3.2.2 Instruments

3.2.2.1 General

The CFM model is used for three different classes of instruments currently cleared at NOMX Clearing.

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2 Commercial margin models (traditional) are SPAN, OMS II and to some extent TIMS. Of these models “Standard Portfolio Analysis of Risk”, or SPAN, developed and implemented by the Chicago Mercantile Exchange (CME) in 1988 is the most well known.

3.2.2.2 Standardized instruments

These are the original instruments cleared by NOMX Clearing since the early 1990th. These instruments are highly standardized and have a quarterly termination dates.

The group includes IMM-FRAs, futures, hybrid forwards with monthly cash settlement, and options on FRAs and forwards. For these instruments the margin requirement includes

- Market value i.e. the aggregated P/L
- Initial margin
- At settlement there is settlement margin
- At payment there is payment margin

3.2.2.3 Generic rate instruments

OTC fixed income instruments such as interest rate swaps, tailor made FRAs and OIS. The clearinghouse's margin model principle for these instruments is that they are mutually cash-collateralized on a daily basis. In effect this is the same as having a daily Mark-to-market ("MtM") that settles the accumulated P/L. For these instruments there is therefore only Initial margin since settlement and payment margin is not used.

3.2.2.4 Repo instruments

The Clearing house's repo clearing service demands that its participants pledge both the market value and the initial margin of each repo transaction. Thus the margin requirement includes the market value and the initial margin. For repo transactions no payment or delivery margin is demanded.

3.2.3 Step by step through the method

The CFM model is from conceptual point of view very easy to understand:

1. Construct a set of yield curves for different credits given today's market prices.
2. Make sure that the market value of the instrument that should be margined can be calculated using these curves.
3. Construct a number of possible future set of yield curves.
4. Calculate market value for the instrument given each set of yield curves.
5. Look at the set of yield curves that give the lowest market value. This will be the margin for this instrument.

Compare this with the explanation to how other margin models work as OMS II or SPAN. It is a very intuitive model. But as always the devils in the details and even though easy to understand the different steps in the above list can be a little complex to actually do. As an example on this it is easy to say "use the curve" but how to construct the curve?

In this validation the different steps will be explained to some extent and the finer details will be available in the corresponding documentation of the model supplied by NOMX Clearing.

3.2.4 Curves

3.2.4.1 General

The construction of yield curves[3] is a central concept of fixed income analysis. In the construction of the curve it is necessary to have accurate prices for a group of instruments[4]

[3] In this document the term "Yield curves" are used for all curve representations of the interest rate term structure. It can be any curve no matter if it is a forward rate curve or some other type of curve.

that function as the basis of the curve construction see (CFM MI, 2013, s. 12). When the curve is constructed it can then be used to price less liquid, or in some case non-traded, instruments with this curve. This feature is of course the reason why this methodology is used to calculate margins in the interest rate market which to the largest extent is an OTC market, with positions in instrument which has no daily trading which could be used for calculation purposes.

3.2.4.2 Curve construction

CFM uses three different curve building techniques in order to create curves used in its calculation of market values and margin requirements

- Discount factor curves: A discount factor curve expresses the present value of cash flows occurring at various times in the future. These curves are boot strapped using cubic polynomials.
- Forward fixing curves: A second type of curve is the Forward Fixing Rate curve which is used when forecasting floating cash flows in the valuation of Generic Rates Instruments. These curves are constructed using piecewise linear interpolation between node points corresponding to the pricing instruments.
- Instantaneous forward rate curves: The last type of curve that is implemented in CFM is the instantaneous forward rate curve. This will be based on a piecewise constant interpolation between node points corresponding to the pricing instruments.

The finer details on the construction of these curves can be found at pages 8-10 (CFM MMG, 2013). Do notice that NOMX Clearing has developed the curve construction techniques in close cooperation with market makers from the larger banks in the Nordic fixed income market.

In the CFM model, discount factor curves are bootstrapped as a cubic spline. A spline is a mathematical term relating to a set of continuously and smoothly connected polynomials, and the use of a cubic version implies that each separate segment of the spline can be described as a cubic polynomial.

There are in general two classes of curve fitting techniques; spline methods and parametric methods. Spline techniques have become widely adopted in yield curve interpolation and cubic splines are one of the most used forms of spline methods. The parametric methods attempt to model the yield curve using a parametric function. An example of a parametric method is the Nelson-Siegel model.

Among the spline methods, cubic spline is a very common method to choose in the construction of yield curves. Cubic splines do provide a great deal of flexibility in creating a continuous smooth curve. One of the advantages of cubic spline interpolation is that it is considered a fast, efficient and stable method of function interpolation.

One disadvantage with the cubic spline method is that the corresponding curves could oscillate in the neighborhood of an outlier. Also, this method of interpolation is weakest at the end of series and tends to overreact to the latest observed data point.

Bootstrapping the curve with the cubic spline method is considered to be appropriate and there is no need to question the choice of method within the scope of this validation report.

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[4] In the documentation referred to as” pricing instruments”

3.2.4.3 Pricing instruments

Exactly witch instruments that are used for curve construction is set by parameters and requires thorough analysis by the Risk Management. A small group can lead to a curve that lacks too many details for accurate pricing, a larger group could on the other hand lead to that the curve is to "jagged" and therefore also lead to less accurate pricing.

3.2.5 Calculating market value

In SPAN (or other standard margin model) the market value of all instruments are taken as externally given input to the model. These models require the clearinghouse to manage market values outside the margin model. Traditionally this has not been a problem since the models are designed for exchange traded derivatives which get closing prices from the exchange.

In the CFM model the issue on calculating a market value is built into the model. Since the majority of the positions (swaps and similar) do not have an externally given market value this has to be calculated using the constructed yield curves. This is of course not something that is unusual; a bank would be doing exactly the same thing with their swap portfolio. In 9.2 Appendix, the "Real market value adjustment" method (RMVA) is described which is a methodology to "centre" the constructed yield curves on the externally given market value for some types of instruments.

The methodology as such is easy to use and understand. The difficult part is to decide if externally given prices is "much better" than prices generated by the constructed yield curves.

3.2.6 Generating curve scenarios

When the curves are constructed the next part of the margin calculation process is to construct possible future curves that will be used for calculation of the market value given each curve. There are several methods that can be used to construct these curves but most of them does in some way use principal components (PC) as the starting point for the discussion.

A thorough description of PC calculations is beyond the scope of this validation but the technique as such is considered to be well known.

Calculations of the principal components of a curve change matrix ΔC are based on the covariance matrix of the yield changes of different maturity points along the yield curve. The covariance matrix is created from calculations of the covariance of all the original variables. The principal components are obtained by calculating the eigenvectors of the covariance matrix. An eigenvector's eigenvalue reveals how much of the curve's total variance that is explained by this eigenvector. By analysing the eigenvectors the explanation factor and importance of each principal component can be obtained. The principal components are then used in a linear combination in order of generating stressed scenarios.

NOMX Clearing has chosen to use the first three PCs for the purpose of generating curve scenarios used in the margin calculations. The first principal component, PC1, represent a parallel shift of the entire yield curve. The second principal component, PC2, is a change of the slope of the curve (twist). The long end goes up while the short end goes down or vice versa. The third principal component, PC3, represent a curvature change (hump). The short and long end increase while the mid-section decreases or vice versa. Together these three principal components explain the majority of the yield curve's historical movement.

NOMX Clearing has chosen to use the actual PC components as basis for the curve generation. Another option would have been using curves with pre set shapes to get a more "financial explanation of the individual shifts". The choice made will get a better fit to actual movements but will on the other hand be a little bit harder to interpret, both internally and externally. This is of course not something that is built into the CFM model itself, but is decided by the parameter setting.

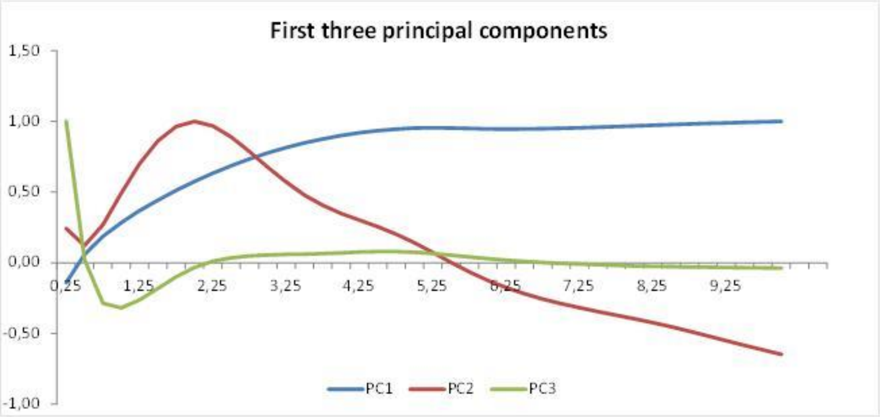

Figure 2: The PC components of the interest rate market

All curves in the CFM model uses the three first PC components as basic input. Each individual PC is then divided in a number of equidistant points (9 PC1, 5 PC2, and 5 PC3). This can be represented as a three dimensional cube:

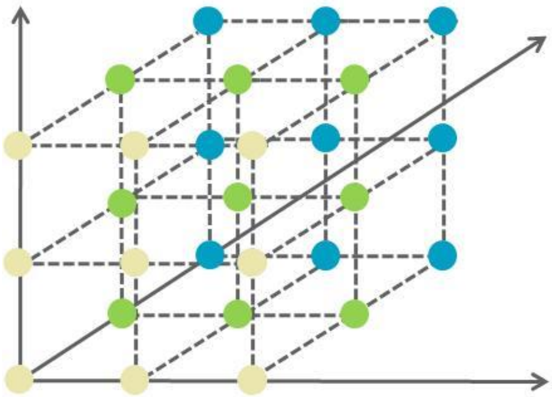

Figure 3: Three dimensional PC grid

Since three dimensional pictures can be somewhat confusing the different PC intervals will be depicted as follows:

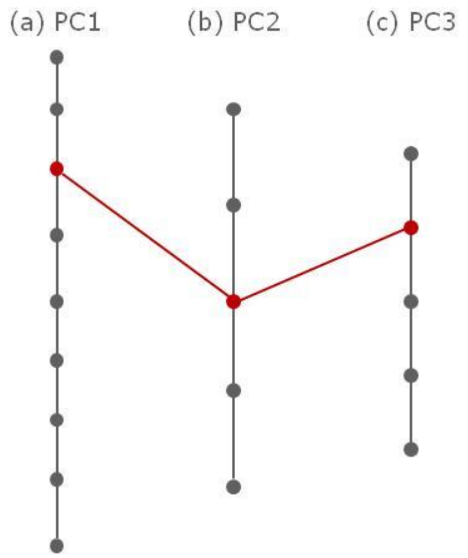

Figure 4: PC grid with one scenario

In the above figure one scenario has been represented by connecting the different “dots” for each PC component. The generation of the scenarios will be noted as this:

$$y_{cred}(t,i,j,k) = y_{cred}(t) + a(i)Pc_1 + b(j)Pc_2 + c(k)Pc_3 \quad (1)$$

$$\left.\begin{aligned} & a(i),\ -4 \le i \le 4 \\ & b(j),\ -2 \le j \le 2 \\ & c(k),\ -2 \le k \le 2 \end{aligned}\right\} \quad (2)$$

Where

$y(t)$	:	The market yield curve for time *t*.
$y(t,i,j,k)$	:	The scenario yield curve for time *t* generated by (*i*, *j*, *k*) scenario
$a(i)$	:	The parameter for PC1. This will be used to multiply the PC1 vector. The *i* will denote what point in the interval that is used.
$b(j)$	:	The parameter for PC2. This will be used to multiply the PC2 vector. The j will denote what point in the interval that is used.
$c(k)$	:	The parameter for PC3. This will be used to multiply the PC3 vector. The *k* will denote what point in the interval that is used.
cred	:	This is the actual credit that the yield curve represents (as swap)

The scenario in Figure 4 will as an example be written as:

$$y_{cred}(t,2,0,1) = y_{cred}(t) + a(2)Pc_1 + b(0)Pc_2 + a(1)Pc_3 \quad (3)$$

To keep it even shorter the scenario will sometimes be referred to as:

$$\{2,0,1\}_{cred,t} \quad (4)$$

When parameters have been chosen and curves generated it is time to use these building blocks for margin calculation.

3.2.7 Calculating margins from the curves

3.2.7.1 General

When the curves are constructed the next part of the margin calculation process is to use these curves and calculate market prices for the positions in the counterparty portfolios. When doing this there are a couple of challenges and situations that must be discussed.

Up to this point there has been discussions regarding individual curves. Usually there are instruments that are defined in different credits. For a portfolio there are situations where multiple yield curves are needed to be able to calculate market value for the instruments in the portfolio.

The two following sections will discuss the two possible situations when calculating margins for a portfolio. The first situation is when a portfolio is only defined in one credit. The other situation is when the portfolio needs several credit curves to be accurately priced.

3.2.7.2 Margin calculations and inter curve correlation

When looking at margin calculations the scenario that produces the worst possible future development of a portfolio is chosen. If the portfolio only consists of positions defined in one type of credit the situation is rather straightforward. The chosen scenario can be defined as:

$$\{x, y, z\}_{cred,t}^{port} = \underset{i,j,k}{\text{Min}}\left[MV_{port}(\{i, j, k\}_{cred,t}) \right] \tag{5}$$

$MV_{port}(\{i, j, k\}_{cred,t})$: The market value calculated for the portfolio given the simulated yield curve $\{i, j, k\}_{cred,t}$

The chosen scenario will be the basis for margin for this portfolio. The numbers of scenarios that will be "tried" are (9·5·5 = 225) different ones. The methodology uses one credit curve for all instruments defined in this credit. This means that from inter curve stand point there is full offset between instruments defined at different parts on the yield curve.

3.2.7.3 Margin calculations and intra curve correlation

In equation (5) the calculations and curve generation is done for one specific credit. In many cases a portfolio has positions defined in several credits. The two extremes in handling this would be treating these credits as:

- Totally uncorrelated credits
- Totally correlated credits
- "Somewhere between" i.e. somewhat correlated

Each of these possibilities will be discussed.

Totally uncorrelated which would mean looking at minimum market value for each credit curve individual and all combinations are possible. For a case with two credit curves this would mean that the minimum market value can theoretically be found when one yield curve increases in all its principal components and the other yield curve decreases in its principal components.

$$\left[\{x_1, y_1, z_1\}_{cred1,t}^{port}, \{x_2, y_2, z_2\}_{cred2,t}^{port}, \ldots, \{x_n, y_n, z_n\}_{credn,t}^{port} \right] =$$

$$= \underset{i_1,j_1,k_1}{\mathrm{Min}}\left[MV_{port}(\{i_1,j_1,k_1\}_{cred1,t})\right]+$$
$$+\underset{i_2,j_2,k_2}{\mathrm{Min}}\left[MV_{port}(\{i_2,j_2,k_2\}_{cred2,t})\right]+...+\underset{i_n,j_n,k_n}{\mathrm{Min}}\left[MV_{port}(\{i_n,j_n,k_n\}_{credn,t})\right] \quad (6)$$

The minimum market value is calculated by looking at the minimum value for each credit independently.

Totally correlated which means that minimum market value is searched for the same movement in principal components for all credits.

$$\left[\{x,y,z\}^{port}_{cred1,t},\{x,y,z\}^{port}_{cred2,t},...,\{x,y,z\}^{port}_{credn,t}\right]=$$
$$=\underset{i,j,k}{\mathrm{Min}}\left[MV_{port}(\{i,j,k\}_{cred1,t},\{i,j,k\}_{cred2,t},...,\{i,j,k\}_{credn,t})\right] \quad (7)$$

Each scenario is investigated for the whole portfolio and for all credits.

Clearly these extremes are not in any way optimal for the margin calculation methodology. This is however not surprising since the issue of correlation is something that all margin models (as well as most VaR models) recognizes as the greatest challenge to handle. Most margin models apply quite step motherly approach to correlation, meaning a low offset between correlated instruments.

The correlation model used by CFM is called “The hyper cube model” which is an extension of the window methodology for correlation used in the OMS II margin model. It could also be called “window methodology for three dimensions” since that is the main difference between the one used in OMS II and the implementation in this CFM model.

The description on hyper cube methodology can be found in the section “Correlation of different yield curves” in pages 33-37, (CFM MMG, 2013) but the methodology will be described in further detail in this document since it is important that the actual calculations are clear to the reader.

The model states that if one individual PC component for one credit curve goes to one specific point in its PC interval the other credits PC (same PC) cannot move to all points in its interval. It is restricted to a number of points in the vicinity of the same point as the first credit.

To clarify, the window methodology for 1 dimension first PC is described between Treasury curve and the SWH curve[5] is used as an example.

[5] Do notice that the MV imply that the other PCs are excluded from this example to facilitate reading.

TREASURY_SEK			SWHO_SEK				Group 1		
PC 1	Point	MV (tkr)	PC 1	Point	MV (tkr)		PC 1	Point	MV (tkr)
26,00	4	-286	28,00	4	-250	→	n/a	4	-611
19,50	3	-242	21,00	3	-280		n/a	3	
13,00	2	-232	14,00	2	-325		n/a	2	
6,50	1	-222	7,00	1	-350		n/a	1	
0,00	0	-139	0,00	0	-395		n/a	0	
-6,50	-1	-77	-7,00	-1	-410		n/a	-1	
-13,00	-2	-72	-14,00	-2	-430		n/a	-2	
-19,50	-3	-66	-21,00	-3	-470		n/a	-3	
-26,00	-4	-48	-28,00	-4	-500		n/a	-4	

Figure 5: First row window for PC 1

TREASURY_SEK			SWHO_SEK				Group 1		
PC 1	Point	MV (tkr)	PC 1	Point	MV (tkr)		PC 1	Point	MV (tkr)
26,00	4	-286	28,00	4	-250		n/a	4	-611
19,50	3	-242	21,00	3	-280	→	n/a	3	-636
13,00	2	-232	14,00	2	-325		n/a	2	
6,50	1	-222	7,00	1	-350		n/a	1	
0,00	0	-139	0,00	0	-395		n/a	0	
-6,50	-1	-77	-7,00	-1	-410		n/a	-1	
-13,00	-2	-72	-14,00	-2	-430		n/a	-2	
-19,50	-3	-66	-21,00	-3	-470		n/a	-3	
-26,00	-4	-48	-28,00	-4	-500		n/a	-4	

Figure 6: Second row window for PC 1

TREASURY_SEK			SWHO_SEK				Group 1		
PC 1	Point	MV (tkr)	PC 1	Point	MV (tkr)		PC 1	Point	MV (tkr)
26,00	4	-286	28,00	4	-250		n/a	4	-611
19,50	3	-242	21,00	3	-280		n/a	3	-636
13,00	2	-232	14,00	2	-325		n/a	2	-681
6,50	1	-222	7,00	1	-350	→	n/a	1	-652
0,00	0	-139	0,00	0	-395		n/a	0	
-6,50	-1	-77	-7,00	-1	-410		n/a	-1	
-13,00	-2	-72	-14,00	-2	-430		n/a	-2	
-19,50	-3	-66	-21,00	-3	-470		n/a	-3	
-26,00	-4	-48	-28,00	-4	-500		n/a	-4	

Figure 7: Fourth row window for PC 1

This sliding movement is continued until all points have been included in the calculations. Let us now perform the calculations for two dimensions i.e. the first and second PCs.

TREASURY_SEK						
PC 1	Point	MV (tkr)				
26,00	4	-172	-229	-286	-344	-401
19,50	3	-145	-194	-242	-291	-339
13,00	2	-139	-186	-232	-278	-325
6,50	1	-133	-177	-222	-266	-310
0,00	0	-83	-111	-139	-167	-195
-6,50	-1	-46	-62	-77	-93	-108
-13,00	-2	-43	-57	-72	-86	-100
-19,50	-3	-40	-53	-66	-80	-93
-26,00	-4	-29	-38	-48	-57	-67
	Point	2	1	0	1	2
	PC 2	16,00	8,00	0,00	-8,00	-16,00

SWHO_SEK						
PC 1	Point	MV (tkr)				
28,00	4	-350	-300	-250	-200	-150
21,00	3	-392	-336	-280	-224	-168
14,00	2	-455	-390	-325	-260	-195
7,00	1	-490	-420	-350	-280	-210
0,00	0	-553	-474	-395	-316	-237
-7,00	-1	-574	-492	-410	-328	-246
-14,00	-2	-602	-516	-430	-344	-258
-21,00	-3	-658	-564	-470	-376	-282
-28,00	-4	-700	-600	-500	-400	-300
	Point	2	1	0	1	2
	PC 2	17,00	8,50	0,00	-8,50	-17,00

Group 1						
PC 1	Point	MV (tkr)				
n/a	4					
n/a	3					
n/a	2					
n/a	1		-816			
n/a	0					
n/a	-1					
n/a	-2					
n/a	-3					
n/a	-4					
	Point	2	1	0	1	2
	PC 2	n/a	n/a	n/a	n/a	n/a

Figure 8: 4, 2 rows window for PC 1 & PC 2

For two PCs the window is a two dimensional area “floating round”. The extension to a three dimensional cube for all three PCs can be illustrated with the following picture[6].

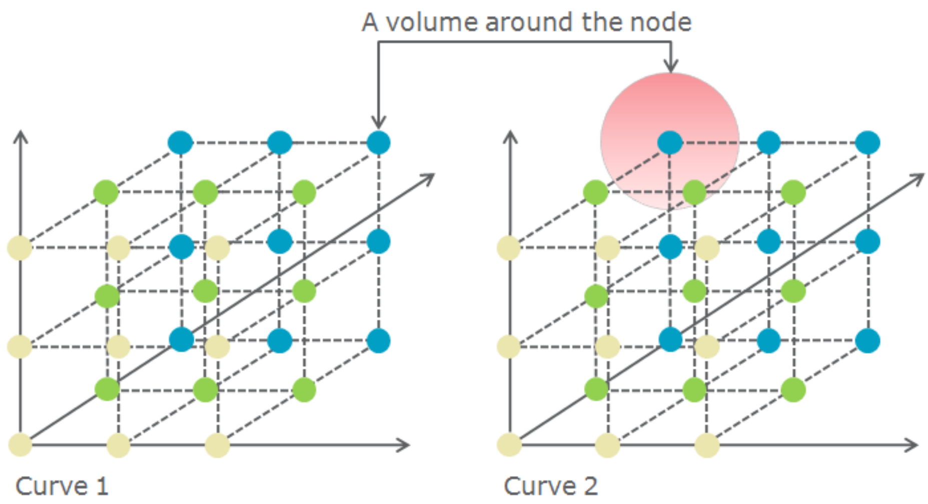

Figure 9: The hyper cube for all three PCs

In Figure 8 there is a resulting group that is constructed from the included yield curves. It is possible to have the groups included in consecutive hyper cubes in a tree like fashion, as the following picture show:

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[6] In reality the volume around the node is a cube and not a sphere

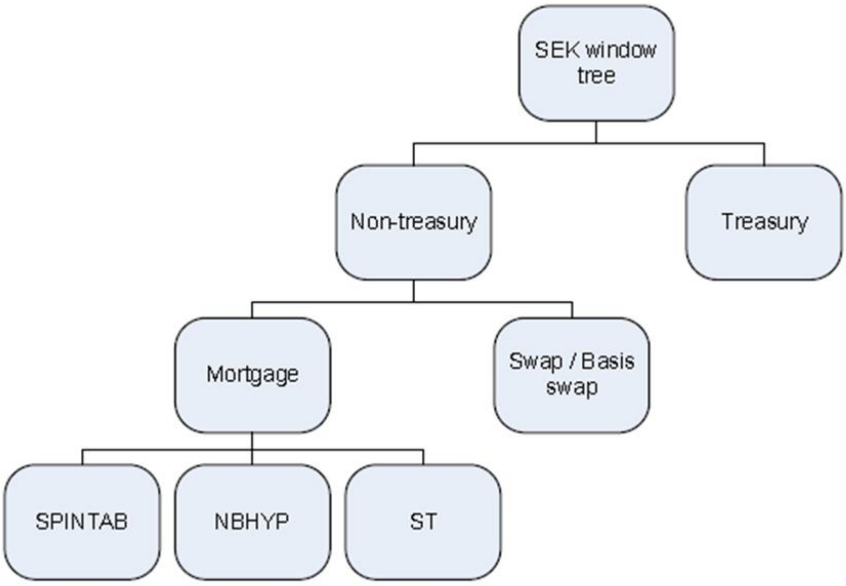

Figure 10: Example on window tree

The methodology of adjusting for correlation between credits does have both pros and cons. The pros are that the actual correlation can be calibrated for the more extreme movements rater than the daily movements which is a very good feature for a margin model. The cons are that since the model is a stepwise methodology it is crucial how the “tree” is chosen and it requires more work of calibrating the tree compared to a more common “correlation matrix approach.

3.2.8 Controlling the algorithm

In the CFM model there is many ways of changing the way the model calculates margins. These are the most important risk parameters:

Principal Components (PC)	:	The shape of the Eigenvectors
Risk Parameters	:	The size of stressed applied to each Principal Components
Scanning range	:	The resolution in each PC
Correlation cube	:	All curves within a correlation cube will have inter curve correlation
Overlapping nodes	:	Decides the limit on how much the applied stress in each PC can vary for curves in the same correlation cube
Buy/sell spread	:	A spread applied to the each individual cash flow
Spread stress margin	:	Some instruments are exposed to movements in two curves – the forward curve and the discounting curve. The changes in these two curves are generally highly correlated; however changes in the spread between the two curves do occur. The Spread stress margin applies a stress between the curves.

Market value adjustment[7]	:	Specifies whether the margin value should be adjusted for the difference between the actual Market Value, Market value from the two-curve logic, and the one established from a one-curve approach.
Minimum number of nodes	:	Specifies the number of instrument series that are required to construct the yield curve.
Minimum number of days between nodes	:	Specifies the minimum number of calendar days between the maturity of two instrument series that will be used to make up the yield curve. If two subsequent series (starting with the nearest maturity) have maturity dates being closer than the specified number of days, one of them will be discarded from the yield curve construction
Curve construction method	:	Specifies what method should be used to construct the curve
Priority filter	:	Specifies which instruments to use when building each curve. The priority filter is also used when determining which instrument series to discard if the maturity of two selected instrument series are closer than Minimum number of days between nodes
Risk free interest rate	:	Risk-free interest rate used when evaluating options. The simple interest rate is translated to a continuous rate. It is possible to enter tenor and rate as pair in the system. In this way a rudimentary yield curve can be constructed. In most set ups this is not the case since the relative effect of the interest rate in option pricing is limited.
Highest volatility for bought options	:	Applies only to bought options and effectively limits the value of the option since volatility is one of the most important part of the valuation.
Adjustment for erosion of time value	:	The number by which the number of days to maturity will be reduced when evaluating held options. This is a way of adjusting for the fact that when the defaulting parts positions are neutralized the time value of the options has decreased.
Lowest volatility for sold options	:	Applies only to sold options and effectively limits the lower value of the option since volatility is one of the most important part of the valuation.
Volatility shift parameter	:	Fixed parameter that determines the size of the volatility interval. In the previous section a three step interval was used for volatility. The normal parameter here is 10% (in absolute terms)
Volatility spread	:	Defines the spread for options. The spread parameter is a fixed value.

[7] See Appendix 9.2 for description of this feature.

Highest value bought in relation to sold options	:	Min. spread between the values for bought and sold options if spread is too small the value of the bought option is decreased
Adjustment for negative time value	:	If the theoretical option value is lower than the intrinsic value, the price is adjusted to equal the latter.

3.3 Purpose & Limitations

3.3.1 Instruments and markets

3.3.1.1 Linear contracts

The CFM model is used for three different classes of linear contracts.

- Standardized contracts
  - ✓ IMM-FRAs
  - ✓ Futures
  - ✓ Hybrid forwards with monthly cash settlement
- Generic rate contracts
  - ✓ Interest rate swaps
  - ✓ Tailor made FRAs and OIS
- Repo contracts

3.3.1.2 Option contracts

The majority of fixed income instruments are linear products but there are options among the cleared contracts. These are options on the standardized contracts as FRAs and forwards.

In the CFM model the underlying price (or interest rate) for the option will be calculated using the yield curves but the option will be calculated using:

- B76 option formula[8] for European style options
- For cases were interest rates are very low Bachelier option formula would be used since it accommodates for negative interest rates, which is not possible in B76. A comparison between the approaches can for example be found in pages 124-125 (AvSergio Albeverio, 2003)
- For option with early exercise (American style) a common binomial lattice model will be used.

3.3.2 Market conditions for the model

3.3.2.1 General on market state

The financial market is not a quiet, stable and calm system. On the contrary, markets tend to have different states that are defined in different volatilities and correlation structures for the underlying prices in the market.

A very crude way of connecting different models to market states can be done according to the following picture:

[8] Very commonly used in the industry for interest rate options with a low grade of complexity. For more complicated instruments a curve based approach would be necessary but for the options currently cleared by NOMX Clearing this is not the case.

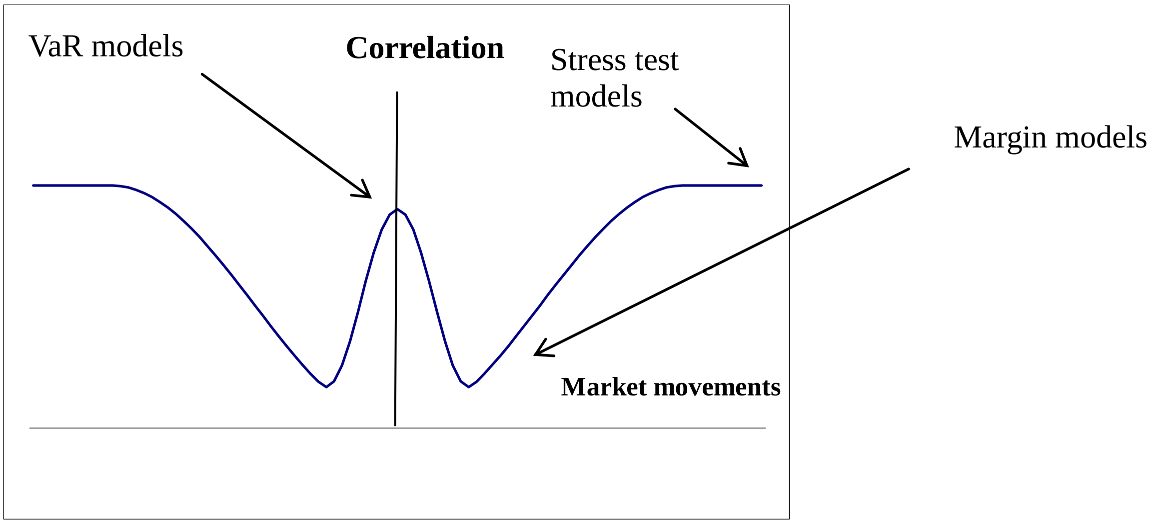

Figure 11: Market movements and correlation

This is only indicative on the usage of models but can be useful for the validation since it points at interesting areas which should be investigated in this document. A VaR model has its merits by its ability to accurately predict risks. Its usual usage is very much focused on day to day markets. Sometimes used as risk mandate calculation in funds or trading environment. This means that the model is used were market movements are small, or rather were the larger amount of market movements can be found.

Traditional margin models tend to treat correlation very step motherly and concentrate on individual volatility on separate underlying. The movements are in many cases caused by individual events for the underlying and uncorrelated with the rest of the market. This could be before annual reports or media coverage attributed to certain company specific events.

CFM is a margin model that can be used as a traditional VaR model. This will of course demand a higher degree of numerical assurance that the CFM model can handle larger movements than the day to day ones.

Stress test models are used in those rare events when market crashes lurks. In these areas the number of observations is very rare making statistical measures uncertain[9]. For these stress tests it is usual to consider high positive correlation in the methods, “everything moves together in a crash”.

3.3.2.2 Correlation within a curve

The basic concept for a yield curve approach is that all credits defined on the same yield curve can be valued with the same curve. This is the key issue when correlation within a yield curve is discussed. In essence this means that the future development of a yield curve, defined by generating new curves from the three first PC components, must be resilient against higher volatility. I.e. it cannot just be nice fit for the daily movements it must suit a more volatile market.

3.3.2.3 Correlation between curves

Two credit yield curves have relative movements between them. It is important that any correlation methodology (as the “hyper cube”) can accommodate these relative movements during higher volatility. I.e. the correlation methodology will give offset between positions

[9] This is the usual objection when using a VaR model as stress test model with high confidence level.

defined in different credits based on a behaviour that can be found during stressed market behaviour. In Figure 11 it can be seen that CFM will used in an area where correlation can be hard to estimate.

3.3.3 Calculation issues

In history all margin models were used to calculate margin numbers. During the last year the models has also been used in looking at intraday risk. A margin model looks at how much margin a counterpart should pay at a certain point in time (end of day) even if the actual calculations are mad intraday. A risk model on the other hand calculates the risk at that specific moment.

CFM is a new model that has been implemented into the Genium INET system only e few years ago. The model can be used to calculate end of day as well as intraday margin calculations without any difficulties.

Intraday calculations can be made with static yield curves or updated curves during the day. This is more an issue regarding the accuracy of the prices of the pricing instrument than if the CFM model as such can perform the calculations.

There are no instruments that have CFM as margin model which has issues that makes it hard to calculate risk on in real time. High frequency trading ("HFT") is not common in the instruments that use CFM as margin model.

3.4 Statistical significance

The CFM model is a sort of VaR model so in some aspect there will be some statistical issues regarding the model. A portfolio with positions defined in only one credit will have predictability connected to it. For these portfolios the back testing results should be analysed with this in mind.

The parameters for the PC components will have statistical measures connected to them. The models used for this purpose do have a statistical significance and can be evaluated with back testing techniques. The whole issue regarding "testing exceptions"[10] will be concentrated to this part.

3.5 Risk Factors

When designing a risk model in general the key decision is to decide what factors that do, and should, affect the result of the model. This will of course be governed by what instruments that is traded and on what type of markets.

For interest rate products with very few contracts with any optionality the main risk factors are connected to the yield curves and the development of these over time.

3.6 Academic and industry references

The academic references in this area are very large. To divide yield curves in PC components has been a preferred model for many years.

[10] See Appendix I Definitions for definition of testing exception

3.7 Key assumptions

Using principal components as input to the model do imply that NOMX Clearing relies to some extent that the PC components are stable over time and somewhat resilient during more turbulent periods.

3.8 Historical references

All mathematical models should be evaluated based on the usage of the model. It is virtually impossible to have an opinion on a margin model if it is unclear what is expected of it.

In the middle of 1990th the cleared interest rate market was introduced in Sweden. The way this was done was very similar to the rest of the financial industry in Europe and USA. Special constructed options and futures based on interest rate indices tried to make the interest rate market similar to equity and commodity markets. This had some success but the waste majority of instruments were considered too much OTC to be cleared. Granted some reluctance from the member on clearing as such, one of the reason for the failure was that current margin models was not up to the task of actually calculating margins (and risk) on those OTC products.

The introduction of CFM as margin model was to a large extent because of the void in the clearing tool box of actually handling these instruments professionally. The model as such does align very well with how the interest rate community think of risk and also how it calculates on risk. The model has also been developed in cooperation with the larger stakeholders in the interest rate market.

4. Parameters

There are excellent explanations of how risk parameters are estimated within the CFM model. The whole document (CFM RPM, 2013) or (CFM MMG, 2013, p. Appendix II) can be read for this purpose.

In short there are some steps that must be done:

Estimate the three first principal components from the chosen look back period[11] and investigate if the shape is possible to simulate efficient with present set of principal components[12] because changes in the shape of the pc components are more complicated to change and communicate to the stake holders. Size of movements is much easier to deal with.

Estimate size of movements of the individual pc components, change if necessary.

The last action would be calculating widow sizes for the hyper cube methodology. This is also something that is pretty stable and changes here are avoided.

[11] See Appendix I Definitions for definition of look back period

[12] More on this later

5. Monitoring process

5.1 General

The CFM model is a very easy model to describe in casual terms. “Take a curve, simulate several curves chose the worst one, and voila! You are done”. But as always nothing is free and for this model the details needs to be carefully analyzed in order to validate this margin model. Therefore this section on monitoring the margin model is larger than compared with standard margin models which is quite straight forward in the details but might be considered harder to explain in broad terms.

The monitoring process will have two separate parts:

- One part will concentrate on the actual technique with yield curves. How well does the yield curve describe actual development of interest rate, stability etc
- The second part is more like standard margin models which focus on how the CFM model generates margins and how the model behaves given the actual cleared interest rate market.

5.2 Monitoring the yield curve model

A lot of this validation will be discussion regarding numerical analysis and therefore some definitions must be done.

Change curve, “CC”: The change curve is the actual change between the yield curve[13] of today and yesterday. It is of course a function of maturity and credit.

$$y_{cred}^{cc}(t) = y_{cred}(t) - y_{cred}(t-1) \tag{8}$$

Best fit curve, “BFC”: When looking at the actual movement of a yield curve there is a question what values (*a*, *b*, *c*) for our PC1, PC2 and PC2 functions that would fit this change curve best. The best fit curve is in fact defined by the three values (*a*, *b*, *c*) in the equation (1) that represents the values that minimizes the difference between the best fit curve and the actual curve movement when using the method of lest square on the difference. The way this BFC is chosen is described in page 2 (CFM RPM, 2013)

The BFC would be the combination of the principal component functions that “best” estimated the difference between the actual curve changes between two consecutive days[14].

$$\{x, y, z\}_{cred,t}^{BFC} = \underset{i,j,k}{\text{Min,sq}}\left[\{i, j, k\}_{cred,t} - y_{cred}^{cc}(t)\right] \tag{9}$$

Daily explanation factor, “DEF (E_t)”: An interesting issue is if a representation of the yield curve by the principal components accurately describes the actual changes of the curve. There are for one specific day two interesting vectors. The actual change vector with each investigated node of the curve represented by actual daily change of the yield curve, ($\overline{C}_t$). The other vector is the projection of the BFC on each node thereby creating a change vector

[13] For the discussion there is no distinction what representation of the credit curve that is referred to, it can be a discount curve or spot curve or any other representation.

[14] In the examples there will be one day though most products would have a higher number of lead days

generated by the BFC, ($\bar{C}'_t$). By calculating the squared sum of each vector and dividing them one get a measure on how well the principal components describe the actual historical change of the curve; N is the number of nodes for the yield curve.

$$E_t = \frac{\sum_{n=1}^{N} \left(\bar{C}'_{t,n}\right)^2}{\sum_{n=1}^{N} \left(\bar{C}_{t,n}\right)^2} \tag{10}$$

Explanation factor, “EF (E)”: By looking at the daily change vectors for a longer period a more stable measure of how well the principal component projection estimate the actual changes; T is the number of look back days.

$$E = \frac{\sum_{t=1}^{T} \sum_{n=1}^{N} \left(\bar{C}'_{t,n}\right)^2}{\sum_{t=1}^{T} \sum_{n=1}^{N} \left(\bar{C}_{t,n}\right)^2} \tag{11}$$

The explanation factor will be a number in percent between 0 and 100 %. Exactly what levels that constitutes a “good enough fit” will be discussed in the numerical part.

5.3 Monitoring the behavior of CFM calculations for the cleared positions

For the way the CFM model margin interest rate instruments the normal tools will be used in the numerical part of the document i.e.:

- Back testing
- Stress testing
- Sensitivity testing

6. Numerical data

6.1 The control frame work of the CFM model

For a model the numerical control frame work is instrumental in supervising the usage of the margin model. It is very rare that a mathematical model is “wrong”. That would be using assumptions in the model that are clearly not logical or against all financial experience.

What is important is that a model is used within an appropriate environment. This includes types of instruments, markets, market states (the obvious part being high or low financial volatility). This is the main task of a numerical control frame work. By investigate the outcome of the model against the actual market behaviour it can be decided if the model can be used within the present financial environment.

The CFM model is from conceptual point of view very easy but has some complicated part build into the assumptions. This implies the need for two different set of numerical investigations. One set of numerical data for the entire model behaviour, very much like a more standard margin model would have and one set of data which aims at investigating the key assumptions in the model. This last data will be referred to as model testing.

In the model testing typical questions could be if the yield curve describes the interest rate structure in a nice manner? Are the three first principal components enough to describe the development of the yield curve? Etc.

The guiding policy framework regarding back testing, stress testing, sensitivity testing and margin parameter estimation will be used as sources of information in this investigation but will not be validated as individual processes.

6.2 The interest rate instruments

To get a feeling for sizes of instruments and how the risk is distributed in the market the following table can be investigated. It is naked margin (no correlation effect) that is summed up for all instruments.

Instrument	Naked Initial Margin
Bond fwd	-7 096 643 525
Swaps	-3 895 763 294
Repos	-2 223 666 284
FRA	-2 142 865 203
RIBA	-322 857 605
NFRA	-223 390 905
FRA opt	-123 545 545
MBF	-92 723 438
Bond options	-22 685 062

Table 1 : SEK, Naked margin per Instrument type, 20141031

6.3 CFM Back testing

6.3.1 General

Back testing is a technique that is used to control whether the behaviour of a mathematical model behaves as expected/desired. NOMX Clearing has two different automatic back testing set ups:

- Traditional enterprise back testing[15] which is a daily check of how the calculated initial margin of actual portfolios copes with the actual market movements.
- A relatively new model level back testing in which the initial margin of theoretically constructed positions checks against the actual historical market movements.

There is a broad range of different reports that aim at describing the results from the back testing program at NOMX Clearing. This involves both types of back testing and both will be included in this additional validation.

6.3.2 Model back testing

This is a very ambitious back testing program and involves both theoretical portfolios as well as actual clearing portfolios. Having a back testing that is not only performed for the daily changes (as enterprise back testing that will be discussed later) but is checked against the market moments for a larger amount of history is a very useful addition to the risk management toolbox.

With this NOMX Clearing not only calculates model back testing for the actual counterparty account but also for several sets of theoretical accounts, or rather accounts with theoretical positions.

6.3.2.1 Naked positions

The first set of theoretical positions consists of naked positions (both for short and long positions).

Standardized	FRA standardized	OTC Swap
NAKED NBHYP2XX	NAKED FRA14X	NAKED IRS10Y_YC
NAKED NBHYP5XX	NAKED FRA15O	NAKED IRS12Y_YC
NAKED R10XX	NAKED FRA15R	NAKED IRS15Y_YC
NAKED R2XX	NAKED FRA15U	NAKED IRS1Y_YC
NAKED R5XX	NAKED FRA15X	NAKED IRS20Y_YC
NAKED RIBAH5	NAKED FRA16O	NAKED IRS25Y_YC
NAKED RIBAH6	NAKED FRA16R	NAKED IRS2Y_YC
NAKED RIBAM5	NAKED FRA16U	NAKED IRS30Y_YC
NAKED RIBAU5	NAKED FRA16X	NAKED IRS3Y_YC
NAKED RIBAZ4	NAKED FRA17O	NAKED IRS4Y_YC
NAKED RIBAZ5	NAKED FRA17R	NAKED IRS5Y_YC
NAKED SB5XX	NAKED FRA17U	NAKED IRS6Y_YC
NAKED SPA2XX		NAKED IRS7Y_YC
NAKED SPA5XX		NAKED IRS8Y_YC
NAKED ST2XX		NAKED IRS9Y_YC
NAKED ST5XX		

[15] For all back testing done for NOMX Clearing it is a clean back testing with full recalculation and adjustment for instrument specific events.

Table 2: Theoretical positions that will be used for model back testing program

By looking at historical movements and checking these movements against the initial margin a model level back testing has been performed. This kind of back testing is very beneficial from an analysis stand point for a number of reasons:

- The result is stable since all possible movements for the past period are investigated. Large movements in result must come from changes in the financial environment (correlation, size of movements etc) since the portfolio as such is fixed.
- Breaches, or very near breaches, can be directly analysed and would reveal special market movements that would be potentially dangerous for some types of portfolios
- This information will then be used to make changes in the model and maybe early warning indicators that could be used to mitigate the risk

Looking at the above portfolios with 1 MSEK as nominal amount for a date gives the following tables:

ACC_ID	LONG IM	L Worst BT	L Usage	L Breach	SHORT IM	S Worst BT	S Usage	S Breach
NBHYP2XX	-4 859	-1 310	27%	0	-4 890	-4 365	89%	0
NBHYP5XX	-14 768	-6 506	44%	0	-14 996	-8 344	56%	0
R10XX	-30 290	-13 002	43%	0	-31 030	-27 748	89%	0
R2XX	-7 463	-1 978	27%	0	-7 530	-3 918	52%	0
R5XX	-17 487	-6 572	38%	0	-17 755	-11 070	62%	0
RIBAH5	-1 760	-659	37%	0	-1 751	-124	7%	0
RIBAH6	-2 216	-442	20%	0	-2 185	-215	10%	0
RIBAM5	-1 743	-466	27%	0	-1 729	-162	9%	0
RIBAU5	-1 669	-451	27%	0	-1 650	-171	10%	0
RIBAZ4	-887	-304	34%	0	-885	-79	9%	0
RIBAZ5	-1 860	-452	24%	0	-1 841	-184	10%	0
SB5XX	-17 327	-8 135	47%	0	-17 598	-10 132	58%	0
SPA2XX	-8 416	-3 735	44%	0	-8 501	-6 422	76%	0
SPA5XX	-15 370	-6 735	44%	0	-15 606	-8 346	53%	0
ST2XX	-7 523	-1 980	26%	0	-7 591	-5 507	73%	0
ST5XX	-17 327	-8 135	47%	0	-17 598	-10 132	58%	0

Table 3: Model back testing for theoretical "Standardized" positions (2014-10-30, scenario 2 days)

And now the FRA contracts:

ACC_ID	LONG IM	L Worst BT	L Usage	L Breach	SHORT IM	S Worst BT	S Usage	S Breach
FRA14X	-864	-809	94%	0	-862	-382	44%	0
FRA15O	-844	-453	54%	0	-841	-155	18%	0
FRA15R	-777	-452	58%	0	-773	-170	22%	0
FRA15U	-881	-460	52%	0	-878	-209	24%	0
FRA15X	-1 105	-454	41%	0	-1 099	-223	20%	0
FRA16O	-1 123	-431	38%	0	-1 115	-232	21%	0
FRA16R	-1 184	-426	36%	0	-1 172	-270	23%	0
FRA16U	-1 047	-364	35%	0	-1 035	-284	27%	0

FRA16X	-911	-328	36%	0	-898	-308	34%	0
FRA17O	-988	-419	42%	0	-973	-389	40%	0
FRA17R	-846	-481	57%	0	-832	-360	43%	0
FRA17U	-779	-602	77%	0	-765	-468	61%	0

Table 4: Model back testing for theoretical "FRA Standardized" positions (2014-10-30, scenario 2 days)

And the swap contracts:

ACC_ID	LONG IM	L Worst BT	L Usage	L Breach	SHORT IM	S Worst BT	S Usage	S Breach
IRS1Y_YC	-4 554	-1 387	30%	0	-4 491	-539	12%	0
IRS2Y_YC	-11 207	-3 084	28%	0	-11 004	-1 824	17%	0
IRS3Y_YC	-17 988	-5 023	28%	0	-17 541	-3 304	19%	0
IRS4Y_YC	-22 670	-7 701	34%	0	-22 013	-5 258	24%	0
IRS5Y_YC	-25 809	-9 939	39%	0	-24 996	-7 581	30%	0
IRS6Y_YC	-27 245	-11 880	44%	0	-26 358	-9 009	34%	0
IRS7Y_YC	-30 221	-14 004	46%	0	-29 249	-10 052	34%	0
IRS8Y_YC	-33 278	-18 620	56%	0	-32 097	-11 388	35%	0
IRS9Y_YC	-38 232	-20 971	55%	0	-36 557	-12 698	35%	0
IRS10Y_YC	-44 647	-23 588	53%	0	-42 373	-14 621	35%	0
IRS12Y_YC	-55 421	-24 546	44%	0	-51 961	-15 364	30%	0
IRS15Y_YC	-72 770	-30 539	42%	0	-66 849	-18 012	27%	0
IRS20Y_YC	-92 649	-37 711	41%	0	-83 084	-25 312	30%	0
IRS25Y_YC	-86 470	-29 983	35%	0	-74 976	-24 624	33%	0
IRS30Y_YC	-127 130	-52 328	41%	0	-109 086	-32 240	30%	0

Table 5: Model back testing for theoretical "OTC Swap" positions (2014-10-30, scenario 5 days)

The back testing is done for both long and short positions and the usage of initial margin against the worst scenario (for that specific theoretical position) is specified. The look back period is one year. As one can see none of the naked positions show any breaches.

6.3.2.2 Intra curve spread positions

The second set of hypothetical portfolios is very interesting. These are theoretical spread positions between instruments on the same curve (intra curve spreads) and spreads between instruments on different curves (inter curve spreads). Start by looking at the intra curve spread positions. To facilitate reading the table is sorted by usage:

Nr	ACC_ID	PortfolioType	IM	Worst BT	Usage	Breaches
1	B FRA15O- S FRA14X	INTRA_CURVE	-229	-383	168%	3
2	B FRA14X- S FRA15O	INTRA_CURVE	-229	-357	156%	2
3	B FRA16X- S FRA17U	INTRA_CURVE	-313	-348	111%	1
4	B FRA17R- S FRA17U	INTRA_CURVE	-187	-177	94%	0
5	B FRA15R- S FRA14X	INTRA_CURVE	-426	-380	89%	0
6	B FRA14X- S FRA15R	INTRA_CURVE	-427	-380	89%	0
7	B RIBAH5- S RIBAM5	INTRA_CURVE	-227	-201	88%	0
8	B FRA17U- S FRA16X	INTRA_CURVE	-314	-275	87%	0
9	B FRA17O- S FRA17U	INTRA_CURVE	-329	-287	87%	0

10	B R2XX- S R10XX	INTRA_CURVE	-30 707	-25 301	82%	0
11	B FRA16U- S FRA17U	INTRA_CURVE	-388	-317	81%	0
12	B FRA16X- S FRA17R	INTRA_CURVE	-266	-199	75%	0
13	B FRA16U- S FRA17R	INTRA_CURVE	-323	-241	75%	0
14	B FRA17U- S FRA15U	INTRA_CURVE	-498	-366	73%	0
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.	.	.	.	.	.	.
367	B RIBAH6- S RIBAZ5	INTRA_CURVE	-438	-61	14%	0
368	B RIBAH6- S RIBAM5	INTRA_CURVE	-1 117	-149	13%	0
369	B FRA15X- S FRA15O	INTRA_CURVE	-944	-123	13%	0
370	B RIBAZ5- S RIBAH6	INTRA_CURVE	-438	-57	13%	0
371	B RIBAM5- S RIBAZ5	INTRA_CURVE	-781	-97	12%	0
372	B RIBAU5- S RIBAH6	INTRA_CURVE	-874	-107	12%	0
373	B RIBAH6- S RIBAU5	INTRA_CURVE	-872	-107	12%	0
374	B RIBAU5- S RIBAZ5	INTRA_CURVE	-536	-64	12%	0
375	B RIBAM5- S RIBAH6	INTRA_CURVE	-1 119	-132	12%	0
376	B FRA15X- S FRA15R	INTRA_CURVE	-746	-86	12%	0
377	B FRA15X- S FRA15U	INTRA_CURVE	-396	-45	11%	0
378	B RIBAZ5- S RIBAU5	INTRA_CURVE	-534	-60	11%	0
379	PAY 1Y - REC 2Y	INTRA_CURVE	-8 279	-893	11%	0
380	B FRA15U- S FRA15R	INTRA_CURVE	-474	-49	10%	0

Table 6: Theoretical intra curve spread positions, 2014-10-30

This is positions defined on one single yield curve with means that this measure the intra curve spread handling.

There are three occasions for breaches. The reason for these is the interest rate movements at 2010703 when the Swedish central bank unexpectedly lowered the repo rate with 50 basis points. This resulted in a large deviation of the closest forward rate which caused the exception breaches.

Let time between the spread (expressed in days) be the x axis and the Initial margin usage the y axis. Construct separate diagrams for FRAs, Generic and swap spread positions.

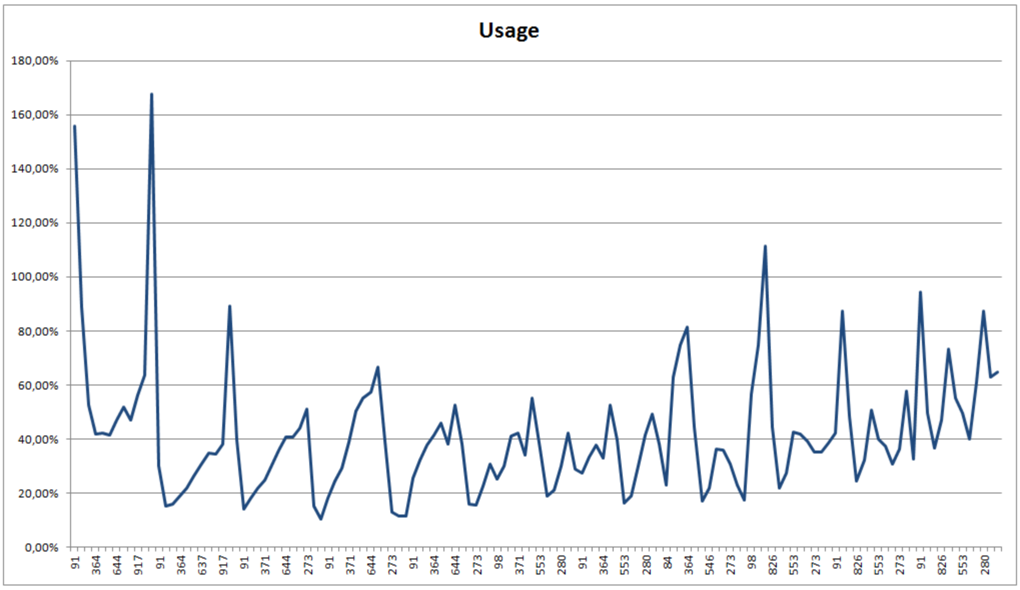

Figure 12: IM usage against the time in days between spread instruments in FRA, 20141030

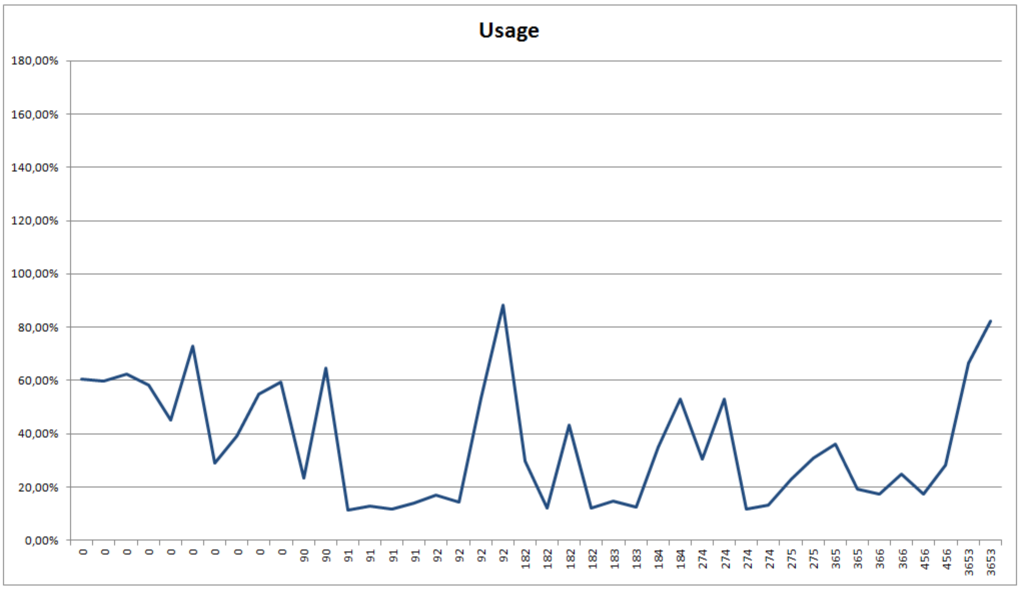

Figure 13: IM usage against the time in days between spread instruments in Generic instruments, 2014-10-30

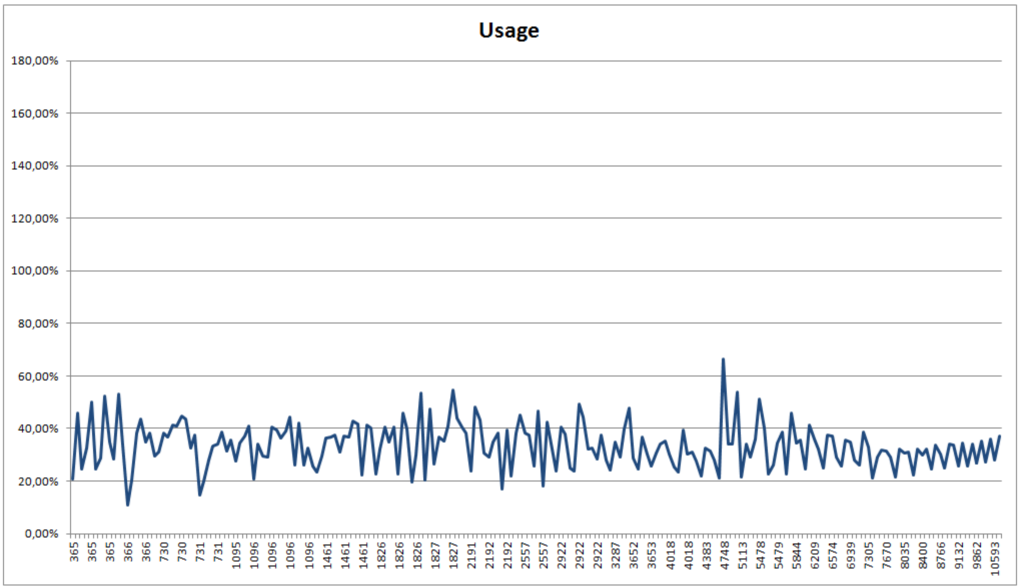

Figure 14: IM usage against the time in days between spread instruments in Generic instruments, 2014-10-30

Both swap instruments and generic instruments are defined on a quite large bit of the yield curve. Swaps via periodical payments during the life span and generic instruments via constructed bonds that often are defined on the whole yield curve. This means that intra curve spread positions in these instruments should be quite well hedged. In the two figures above this feature is shown.

For FRA contracts the different contracts are defined on very small parts on the yield curve because of this the intra curve spread positions can be more volatile which is what Figure 12 show.

A quick table with the average usage for each type of instrument give the following:

Instrument	Nr	Average usage
FRA	132	42%
Generic	42	36%
Swap	206	33%

Table 7: Average usage of initial margin for intra curve spreads

The conclusion from this is that the intra curve behaviour is as expected and the development of the curve does show a quite nice intuitive behaviour when compared against actual historical movements of these types of positions.

Back testing with different liquidation periods

Instruments have different liquidation period which depends on how long it is assumed it would take to close these (liquidation period) in a stressed market. The challenge comes when there are correlated instruments in a margin system that has different liquidation periods. How will these be back tested? If there are 5 days for one instrument and 2 for another one how will the default process be handled? Well if they constitute a hedge for each other it seems ill advised to sell the instruments with two lead days and leave the other in the portfolio.

From practical reason it could be argued that if the instruments with 5 lead days have a hedge instrument with 2 lead days the lead days of the former instrument should be lowered since it is not really that interesting how fast a position can be closed it is how fast the risk can be hedged. In the above calculations the liquidation period has been set to two days for spread positions if there is different number of lead days.

6.3.2.3 Inter curve spread positions

Now it is time to look at the correlation between different credit curves. A similar set of theoretical portfolios with spreads that are based on instruments defined on separate curves are created and margined.

Nr	ACC_ID	PortfolioType	Usage	IM	Worst BT	Breaches
1	S R10XX - REC 1Y	INTER_CURVE	85%	-31 933	-27 111	0
2	S R10XX - REC 2Y	INTER_CURVE	77%	-33 352	-25 733	0
3	S R10XX - B NBHYP2XX	INTER_CURVE	75%	-34 604	-25 796	0
4	S R10XX - REC 3Y	INTER_CURVE	72%	-33 425	-24 063	0
5	S R10XX - REC 6Y	INTER_CURVE	69%	-25 463	-17 604	0
6	S R10XX - REC 5Y	INTER_CURVE	69%	-29 163	-19 992	0
7	S R10XX - B ST2XX	INTER_CURVE	67%	-36 622	-24 603	0
8	S R10XX - REC 4Y	INTER_CURVE	67%	-31 766	-21 338	0
9	S R10XX - B SPA2XX	INTER_CURVE	64%	-37 273	-23 721	0
10	S R10XX - REC 7Y	INTER_CURVE	63%	-24 297	-15 221	0
11	S R5XX - REC 1Y	INTER_CURVE	59%	-17 735	-10 433	0
12	S R5XX - REC 2Y	INTER_CURVE	56%	-16 295	-9 055	0
13	S R10XX - REC 8Y	INTER_CURVE	50%	-24 791	-12 318	0
14	S ST5XX - B NBHYP2XX	INTER_CURVE	49%	-16 647	-8 180	0
.	.	.	.	.	.	.
.	.	.	.	.	.	.
.	.	.	.	.	.	.
746	PAY 5Y - B SPA5XX	INTER_CURVE	6%	-36 369	-2 344	0
747	PAY 5Y - B NBHYP5XX	INTER_CURVE	6%	-35 942	-2 200	0
748	S SPA5XX - B NBHYP5XX	INTER_CURVE	6%	-11 846	-721	0
749	S R2XX - B ST2XX	INTER_CURVE	6%	-13 124	-788	0
750	S R2XX - REC 3Y	INTER_CURVE	6%	-16 055	-961	0
751	PAY 6Y - B NBHYP5XX	INTER_CURVE	6%	-37 374	-2 212	0
752	PAY 6Y - B SPA5XX	INTER_CURVE	6%	-37 800	-2 184	0
753	S ST2XX - REC 3Y	INTER_CURVE	5%	-23 171	-1 193	0
754	S NBHYP5XX - B SPA5XX	INTER_CURVE	4%	-11 636	-522	0
755	PAY 2Y - B NBHYP2XX	INTER_CURVE	4%	-14 783	-658	0
756	PAY 3Y - B ST2XX	INTER_CURVE	4%	-23 582	-1 048	0
757	PAY 2Y - B ST2XX	INTER_CURVE	4%	-16 801	-711	0
758	S SB5XX - B ST5XX	INTER_CURVE	0%	-24 028	0	0
759	S ST5XX - B SB5XX	INTER_CURVE	0%	-24 028	0	0

Table 8: Theoretical intra curve spread positions, 2014-10-30

For these spread positions the "hyper cube window" method is used to take into consideration the correlation between two yield curves. If there would be a lot breaches and a general high usage of initial margin the method could at least be suspected of not doing its job. In order to look at this different spreads in the above Table 7 will be grouped in credits and the correlation between them will be further investigated.

First look at the number of spreads.

Nr	Gov	Swap	SBH	NBH	SPA	STX
Gov						
Swap	90					
SBH	6	30				
NBH	12	60	4			
SPA	12	60	4	8		
STX	12	60	4	8	8	

Table 9: Number of intra curve spreads for different credits

Then look at the largest initial margin usage in the group.

Max usage	Gov	Swap	SBH	NBH	SPA	STX
Gov						
Swap	85%					
SBH	44%	48%				
NBH	75%	41%	42%			
SPA	64%	42%	32%	46%		
STX	67%	45%	34%	49%	47%	

Table 10: Maximum usage of initial margin for intra curve spreads for different credits

Finally there is the average usage of initial margin.

Average usage	Gov	Swap	SBH	NBH	SPA	STX
Gov						
Swap	30%					
SBH	30%	21%				
NBH	30%	22%	26%			
SPA	29%	22%	20%	32%		
STX	28%	21%	17%	30%	35%	

Table 11: Average usage of initial margin for intra curve spreads for different credits

It can be seen that there are a lot of different mortgage credits (SBH, NBH, SPA and STX) which is interesting in itself but it would be good to bundle them up so the three main credit (mortgage, Government and Swap credits) can be investigated. The same type of table as above but with a general mortgage credit instead:

Nr	Gov	Swap	Mort

Gov			
Swap	90		
Mort	42	210	

Table 12: Number of intra curve spreads for different credits, collected mortgage

Max	Gov	Swap	Mort
Gov			
Swap	85%		
Mort	75%	48%	

Table 13: Maximum usage of initial margin for intra curve spreads for different credits, collected mortgage

Average	Gov	Swap	Mort
Gov			
Swap	30%		
Mort	29%	22%	

Table 14: Average usage of initial margin for intra curve spreads for different credits, collected mortgage

The conclusion is that the numerical investigation do imply that correlation between credits (inter curve correlation) are handled in an adequately way by the hyper cube methodology.

The hyper cube methodology is a very conservative model, or at least is used with quite conservative parameters. The initial margin, compared with what historical movements imply, is on a high level.

6.3.2.4 Explanatory power of principal components

Explanatory factor as defined in equation (11) measures how much the observed movement in the market can be explained by the principal components. This is a very well defined mathematical measure and will reveal any periods in which the actual principal components would have been clearly unsuitable to use. By looking at EF for different look back periods the following graph can be constructed:

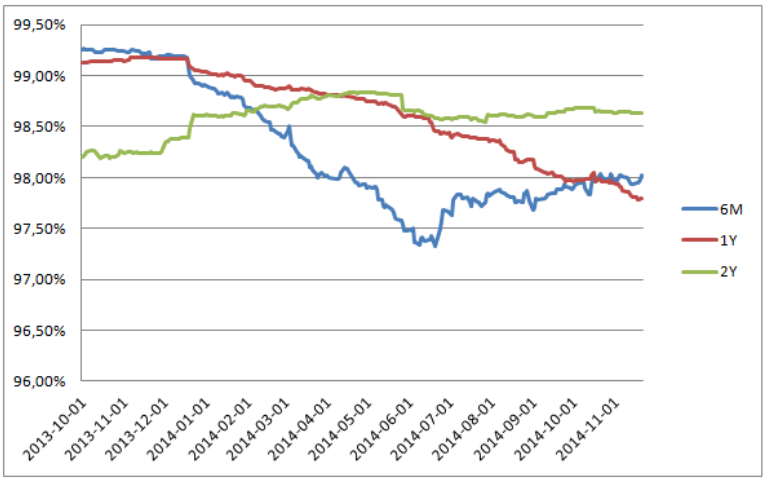

Figure 15: The Explanatory factor (20131001-20141121) for three different look back periods

Because of the high number it can be a conclusion from the validation that the explanatory power of the three PC approach can be well defended for margin calculation purposes.

6.3.3 Enterprise level back testing

The traditional enterprise back testing gives data that looks like this:

Date	Margin	MV t+1	MV t+2	MV t+3	MV t+4	MV t+5	Min	Breach
2014-10-30	-972	-227					-227	0
2014-10-29	-915	-164	-157				-164	0
2014-10-28	-839	-158	-155	-147			-158	0
2014-10-27	-795	-207	-218	-215	-212		-218	0
2014-10-26	-885	-233	-236	-250	-246	-245	-250	0
2014-10-25	-904	-202	-210	-215	-225	-221	-225	0
2014-10-24	-894	-280	-276	-288	-288	-308	-308	0
2014-10-23	-853	-309	-322	-315	-329	-325	-329	0
2014-10-22	-774	-256	-260	-800	-268	-282	-800	1
2014-10-21	-740	-277	-272	-294	-306	-300	-306	0
2014-10-20	-756	-291	-291	-285	-315	-326	-315	0
2014-10-19	-758	-284	-293	-293	-287	-320	-320	0

Table 15: Enterprise back testing (MSEK) for one of the larger bank members

The above table is included for educational purposes. The back testing is done for a few dates and for one of the larger members. For each date the initial margin is calculated and if that position were to be held during the next five days the corresponding market value can be found in the table. For the date 20141022 the initial margin was 774 MSEK and the development of the market value for the portfolio during two days would mean a lowering of the market value of 260 MSEK. If this would have been a larger negative value than the initial margin the account would show a breach[16]. The table show that for this period of time there has been one breach at 20141022 for t+3.

The following table has been done for each portfolio and sorted in Initial Margin usage to illustrate the result of the back testing.

Nr	ACC_ID	Usage	IM	Worst BT	Breach
1	xx1	93%	-1 846 001	-1 719 517	0
2	xx2	93%	-155 788	-144 204	0
3	xx3	92%	-835 474	-770 906	0
4	xx4	90%	-325 294	-293 870	0
5	xx5	90%	-4 947 151	-4 435 357	0
6	xx6	86%	-6 778 928	-5 799 372	0
7	xx7	86%	-324 482	-277 482	0
8	xx8	86%	-4 769 888	-4 078 984	0
9	xx9	83%	-405 047 760	-336 133 635	0
10	xx10	80%	-263 346 059	-210 043 375	0

16 A breach would constitute a situation where the initial margin would be too little to be a cushion for the potential losses. It is however important to understand that this would have been an exposure. The member must of course be in default before the losses would be realized.

.	.	.	.	.	.
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.	.	.	.	.	.
95	xx95	21%	-124 862 830	-26 011 751	0
96	xx96	20%	-51 139 991	-9 975 771	0
97	xx97	19%	-33 645 080	-6 400 630	0
98	xx98	18%	-544 072 433	-99 912 444	0
99	xx99	18%	-14 958 472	-2 677 733	0
100	xx100	17%	-18 556 571	-3 149 311	0
101	xx101	13%	-24 552 560	-3 089 449	0
102	xx102	11%	-2 173 787	-241 826	0
103	xx103	10%	-5 659 872	-578 665	0
104	xx104	10%	-166 874 997	-16 064 119	0

Table 16: Enterprise back testing, 20141030

It can be seen that there are no breaches for any of the accounts. This also emphasizes the conservative calculations done by the CFM model.

6.4 CFM Stress testing

6.4.1 General

Stress testing is to test how a model behaves if "large" changes are made in the basic assumptions or parameters. There can be a lot of different stress tests done to investigate the behaviour of the model and the market in which it is used in. In this additional validation two different stress tests will be used.

6.4.2 Stress testing

6.4.2.1 Explanatory power of principal components for stressed markets

Explanatory factor as defined in equation (11) and discussed in 6.3.2.4 for back testing purposes can also be used for stress test purposes. It is interesting to see if the explanatory power of the PC approach works best in normal day-to-day markets or in stressed market days. By introducing the "average rate change" for each day the data can be ordered by this measure and trends can be discovered.

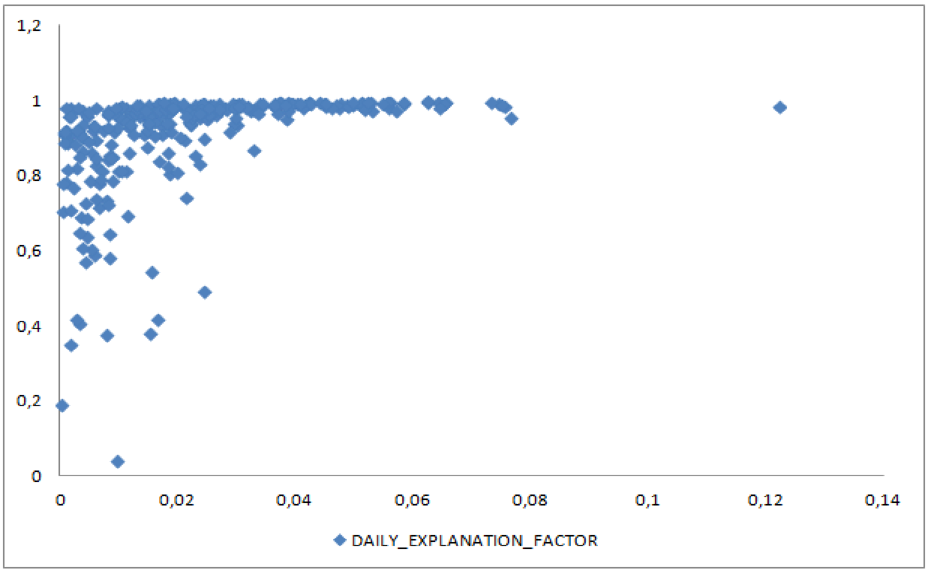

Figure 16: Daily explanation factor vs Average curve point change (%), (20131001-20141121)

From the figure it can be seen that the explanatory factor increases with larger market movements. This is of course a behavior that is very good since it is more interesting for a clearing house with the behavior of its margin models during financial turbulent occasions than on low volatility days.

For stress testing the CCaR[17] calculations is used. Here the PC1 and PC2 components are shifted to the extreme therefore simulating an extreme movement in interest rate markets. The same movement is applied to all accounts in NOMX Clearing that has positions in the interest rate market. After this the initial margin (plus P/L) is deducted from the stressed scenario market value and the residual is the potential loss NOMX Clearing would sustain from this counterpart given the calculated margin and stressed market scenario. The applied CCaR parameters are as follows:

Parameter	Bond fwd (Gov)	Bond fwd (Real-estate)	Repos Gov	Repos Real-estate	FRA	Swap
PC1 CCaR	35	38	43	46	41	64
PC2 CCaR	21	22	26	27	25	40
PC1 CFM	20	20	24	24-28	21	38
PC2 CFM	14	14	17	17	13	29

Table 17: Stressed CCaR parameters compared with the ordinary initial margin parameters

6.5 CFM Sensitivity testing

In this area the different PC margin parameters will be changed and the difference in initial margin will be analysed. 100%PC1 means that the parameter for the first pc component is increased 100% (effectively doubling them). With these new values an ordinary CFM margin calculation is done and the result compared with the unstressed one.

In the first PC component it can be seen that a change in this parameter with 1% do give a change in margin number. By dividing the result with each other the relative movement is

17 CCaR is the methodology currently used by NOMX Clearing to calculate the size of the default fund.

calculated. If this is 100 it is perfectly linear i.e. a 100% change gives 100 times the effect compared with a change of 1%.

Even if this is not 100 it is required of the model to be stable in time since the effect of increasing parameters should be intuitive an stable to facilitate understanding for Risk Management in NOMX Clearing and varies stake holders.

ACCOUNT	1% PC1	100% PC1	PC1 rel	1% PC2	100% PC2	PC2 rel	1% PC3	100% PC3	PC3 rel
435925	-0,95%	-73%	77	0,00%	-12%		0,00%	-6%	
435924	-0,95%	-73%	77	0,00%	-12%		0,00%	-7%	
385204	-0,91%	-75%	82	0,00%	-8%		0,00%	-7%	
437948	-0,89%	-72%	81	0,00%	-14%		0,00%	-7%	
438880	-0,88%	-69%	79	0,00%	-10%		0,00%	-14%	
434927	-0,88%	-76%	87	0,00%	-3%		0,00%	-12%	
434919	-0,88%	-74%	84	0,00%	-14%		0,00%	-5%	
435917	-0,87%	-71%	81	0,00%	-15%		0,00%	-5%	
438311	-0,86%	-71%	82	0,00%	-17%		0,00%	-6%	
437942	-0,86%	-71%	82	0,00%	-17%		0,00%	-6%	
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.	.	.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.	.	.
434780	-0,83%	-67%	80	0,01%	-14%	-1748	0,00%	-12%	
437717	-0,82%	-66%	81	0,00%	-16%		0,00%	-10%	
436547	-0,80%	-63%	79	0,00%	-10%		0,00%	-19%	
437956	-0,79%	-62%	78	0,00%	-15%		0,00%	-8%	
437727	-0,79%	-63%	79	0,00%	-12%		0,00%	-18%	
437730	-0,79%	-62%	79	0,00%	-12%		0,00%	-18%	
437719	-0,79%	-62%	80	0,00%	-12%		0,00%	-19%	
437710	-0,78%	-73%	94	0,00%	-5%		0,00%	-12%	
437943	-0,78%	-62%	80	0,00%	-14%		0,00%	-17%	
437787	-0,78%	-62%	80	0,00%	-14%		0,00%	-17%	

Table 18: Increases in the different PCs and their relative movement, 2014-10-30

By looking at average values for different dates the following table can be drawn:

date	1% PC1	100% PC1	PC1 rel	1% PC2	100% PC2	PC2 rel	1% PC3	100% PC3	PC3 rel
2014-02-27	-0,67%	-58%	89	0,00%	-17%		0,00%	-14%	
2014-03-31	-0,65%	-57%	88	-0,01%	-17%		0,00%	-16%	
2014-04-30	-0,65%	-57%	92	0,00%	-18%		0,00%	-15%	
2014-05-29	-0,65%	-55%	87	0,00%	-18%		0,00%	-14%	
2014-06-30	-0,70%	-58%	85	0,00%	-18%		0,00%	-15%	
2014-07-31	-0,69%	-58%	87	0,00%	-20%		0,00%	-16%	
2014-08-28	-0,70%	-57%	83	0,00%	-19%		-0,01%	-16%	
2014-09-30	-0,66%	-54%	83	0,00%	-20%		-0,01%	-17%	
2014-10-30	-0,65%	-54%	83	-0,01%	-21%		-0,01%	-16%	

Table 19: Average for all accounts on each date in Increases for the different PCs and their relative movement

From Table 19 it can be seen that the relative movements is quite stable, which is the desired result.

7. Conclusions

7.1 Changes from previous validation

Previous validation of the CFM model (Periculo AB, 2013) was supported with an addition to the validation (Addition to validation of CFM, NOMX, 2013). These two documents in combination are to be considered “previous validation” for the CFM model.

- Improved stub handling for swaps (stubs are the periods in a trade that is not aligned to the ordinary cash flow schedule)
  - ✓ Front stub: where the stub period is the first interest rate period in the trade
  - ✓ Back stub: where the stub period is the last interest rate period in the trade
- Allow different effective dates on the different legs (fixed and float) in a trade
- Liability swaps i.e. interest rate swaps with unadjusted coupons

None of these changes would have any larger impact on the usage of the CFM model. The adjustments are small from both conceptual and functional point of view.

There have been no changes in the Nordic interest rate market that would cause the CFM model to be less appropriate for margin purposes.

7.2 Input to the validation

The CFM model is the newest margin model currently deployed at NOMX Clearing. This also means that the model does have the attention from both internal and external stake holders. The knowledge of the model, at least in a rudimentary way, is quite wide spread.

The key personnel do have a thorough understanding of the model and its deficiencies therefore minimizing the operational risk of using the model in a less optimal way.

The documentation of the model, with the Model instruction (CFM MI, 2013) and CFM Margin methodology guide (CFM MMG, 2013) as main reference material does its job with supplying information on the model.

Since parameter estimation is an essential part of the CFM model and more complicated compared with margin models for other margin models, as SPAN and OMS II, the document (CFM RPM, 2013) is also essential for the understanding of the usage of the model.

The documentation is generally of high quality and updated.

7.3 Theoretical framework of the model

The CFM is a new and rather advanced margin model which has both pros and cons. On the positive side there is

- Higher understanding from the member base on the model, less “over margin” feature
- Easier to incorporate new instruments in the model
- Is designed for OTC products which meet the requirements from the member base on how OTC products should be handled
- Small number of parameters to handle, which is good from operational point of view.
- New implementation means easier to solve new IT related demands compared to older model with old implementations

But everything is of course not only “good” there are several challenges with a modern model.

- A more VaR like approach leads to a model that can be sensitive to changes in the financial environment, i.e. changed volatility and correlation structure.
- A more advanced model also means more advanced background on personnel that are to manage the model. Higher cost and demands on education.

The model itself aligns very well with internal models used by banks in the interest rate sector. The theoretical soundness of the model is obvious from the numerical investigation. The model has statistical relevant within one credit but is robust with a step motherly treatment of inter credit correlation which will function as a nice cushion when correlation between credit changes.

The model have parts and details that can be directly related to academic and industry references which is important from the view point of acceptance in the interest rate community, both in Sweden but also internationally.

7.4 Correlation

7.4.1 General

The usage of correlation in the CFM model should meet the demands given by (Del.Reg 153/2013 EMIR, s. Art 27) when it comes to portfolio margining. For this model this breaks down into two separate parts:

7.4.2 Correlation within one credit (inter curve correlation)

Discussed in section “3.2.7.2 Margin calculations and inter curve correlation” in this validation. This was also a subject in (Addition to validation of CFM, NOMX, 2013, s. sec. 5.5). The issue is if instruments defined on different credit curve can be margined using the “hyper cube” methodology and be in accordance with EMIR. Previous investigations do show that this is in accordance with EMIR. No new issues have been discovered that would render this decision non suitable.

It is also the case that the correlation method applied is a purely numerical method and can, and is, calibrated to be very conservative in offset given.

7.4.3 Correlation between credits (intra curve correlation)

Discussed in section “3.2.7.3 Margin calculations and intra curve correlation” in this validation. This was also a subject in (Addition to validation of CFM, NOMX, 2013, s. sec. 5.4) together with (CFM, Intra Memo, 2013). The issue is if instruments defined on the same credit curve can be margined using the same curve or if this give too much correlation effects. Previous investigations do show that this is in accordance with EMIR. No new issues have been discovered that would render this decision non suitable.

For this correlation risk NOMX Clearing applies the parameter “Buy/sell spread” defined in 3.2.8 Controlling the algorithm that ensures that cash flows on a credit curve will be subjected to a spread. This means that even positions that are to some extend fully correlated on a credit curve will lead to some margin calculated for that position.

7.4.4 Conclusions

From the stand point of the validation the usage of CFM when it comes to correlation meet all criteria’s set by the EMIR frame work.

7.5 Parameters

For traditional margin models the methodology for estimating scanning range has very little to do with the margin model used. The methodology for estimation of principal components, and to decide if they are appropriate for certain intervals, is in many ways directly connected to the CFM model. This means that the general way parameters are estimated expressed in (Policy for setting risk parameters, 2014) must be individually adjusted for the CFM model.

7.6 Monitoring process

NOMX Clearing has an ambitious back testing and sensitivity testing program at place which facilitates the monitoring of the model. Changes in the way the model behave or changes in the surrounding environment would quickly be discovered.

7.7 Recommendations

There were no material recommendations from previous validation or from the addition to the previous validation.

A minor recommendation to NOMX Clearing is to make an effort to construct a report package in a more standardized way. The CFM model is more advanced than other comparable models in NOMX Clearing and the extraction of data is more delicate in the CFM model since it is a more complicated model and the possibilities of making errors are higher. A package can be constructed in a more structured way thereby avoiding ad hoc data extraction for future model validations and of course for other purposes.

8. Information

8.1 Figures

8.2 Tables

8.3 References

Addition to validation of CFM, NOMX. (2013). *Addition to validation of CFM ver 1.0 2013.*

AvSergio Albeverio, W. S. (2003). *Lectures on Probability Theory and Statistics.* Berlin Heidelberg: Springer.
CFM MI. (2013). *CFM Model instructions.* Stockholm.
CFM MMG. (2013). *Margin methodology guide for Nordic fixed income products.* Stockholm.
CFM RPM. (2013). *CFM Risk Parameter Methodology.* Stockholm.
CFM, Intra Memo. (2013). *Intra-curve margin off-set in CFM under stressed market conditions.* Stockholm.
Periculo AB. (2013). *Validation of CFM Model.* Stockholm.
Policy for setting risk parameters. (2014). *Policy for setting risk parameters.*
Validation of CFM, NOMX. (2013). *Validation of CFM ver 1.0, 2013.*

9. Appendices

9.1 Appendix 1 Definitions

To facilitate reading the definitions of COMMISSION DELEGATED REGULATION (EU) No 153/2013, CHAPTER I, GENERAL, Article 1 Definitions is included in this appendix to the validation.

For the purposes of this Regulation, the following definitions apply:

1) ‘basis risk’ means the risk arising from less than perfectly correlated movements between two or more assets or contracts cleared by the central counterparty;
2) ‘confidence interval’ means the percentage of exposures movements for each financial instrument cleared with reference to a specific lookback period that a CCP is required to cover over a certain liquidation period;
3) ‘convenience yield’ means the benefits from direct ownership of the physical commodity and is affected both by market conditions and by factors such as physical storage costs;
4) ‘margins’ means margins as referred to in Article 41 of Regulation (EU) No 648/2012 which may include initial margins and variation margins;
5) ‘initial margin’ means margins collected by the CCP to cover potential future exposure to clearing members providing the margin and, where relevant, interoperable CCPs in the interval between the last margin collection and the liquidation of positions following a default of a clearing member or of an interoperable CCP default;
6) ‘variation margin’ means margins collected or paid out to reflect current exposures resulting from actual changes in market price;
7) ‘jump to default risk’ means the risk that a counterparty or issuer defaults suddenly before the market has had time to factor in its increased default risk;
8) ‘liquidation period’ means the time period used for the calculation of the margins that the CCP estimates necessary to manage its exposure to a defaulting member and during which the CCP is exposed to market risk related to the management of the defaulter’s positions;
9) ‘lookback period’ means the time horizon for the calculation of historical volatility;
10) ‘testing exception’ means the result of a test which shows that a CCP’s model or liquidity risk management framework did not result in the intended level of coverage;
11) ‘wrong-way risk’ means the risk arising from exposure to a counterparty or issuer when the collateral provided by that counterparty or issued by that issuer is highly correlated with its credit risk.

9.2 Appendix 2 Real market value adjustment

In CFM there is a method called “real market value adjustment”, “RMVA” which is a way of adjusting (centre) the initial margin calculation to the actual externally market value given by the market. The methodology is described at pages 19-30, (CFM MMG, 2013). The method is also discussed at pages 6-7, (Periculo AB, 2013).

The issue of “accurate” market prices is something that is discussed in all clearing houses for all margin models. In some cases the pricing issue is solved within the margin model and in some cases it is handled outside the model. In NOMX Clearing there is a mix were pricing is held outside the model for SPAN and FX (historical simulation) whereas in OMX II and to some extent in CFM the pricing is built in to the model.

The methodology takes the calculated theoretical market value vale for an instrument and compares it to the externally given market value. If there is a difference this difference is added/subtracted from the theoretical market value within the margin calculations, thus “centre” all the results to the actual market value.

For interest rate instruments there are few official closing prices[18] that can be considered “accurate market prices”. Most prices suffer from the usual sources of errors:

- A low liquidity means that the closing price can sometimes be hours old
- Some instruments can have a high demand due to other financial reasons. There could as an example be high demand for deliveries in some instruments due to other OTC constructions that would temporarily generate “unrepresentative” prices for the instrument given a comparison with other instruments in the same credit class.

Therefore the RMVA methodology should only be used in the case were NOMX Clearing is absolutely sure that the closing market prices of the cleared instruments (externally given market value) are of higher quality than the market value generated by the margin calculations.

From the standpoint of the RMVA methodology should be used under the following circumstances (which also should be included in a process for this decision):

1. The theoretical market value calculation in the margin model must be an approximation and calculated by the model.
2. The “true” market value must be of consistently higher quality and accuracy compared with the theoretical prices. It could be calculated within the margin model but in most cases these prices will be extracted from the “market”
3. There should be a clear financial reason for this methodology to be used. Applying the model for “very small” differences would increase the complexity of reproducing the margin calculations (and understanding) without a substantial benefit to the stakeholders.

From the standpoint of this validation the methodology as such has merits but the benefit from using it depends on the quality of the market prices. Looking at the swap instruments and following the above process would give the following results:

[18] There are of course official prices for some interest rate products and others have calculated prices from vendors (as Reuters) that function as such. This document will however refer to closing prices without making any difference between the different mechanisms of obtaining these prices.

1. Yes the market values are based on interest rates estimated from the generated curves in the model.
2. Yeas the two curve methodology is implemented in cooperation with the market members and is of higher accuracy compared with the one curve approach in initial margin calculation.
3. Yes the "true" market value is used as Mark-to-market and that means that the actual market values have a significant meaning to the members and that lists etc. with other market value numbers than the one calculated with the two curve approach would not be of any use to the members.

The validation finds that the current usage of the method restricted to Generic Rates Instruments is a prudent limitation.