NASDAQ OMX CASH FLOW MARGIN

Methodology guide for margining Nordic fixed income products.

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NASDAQ OMX Stockholm (NOMX)

DOCUMENT INFORMATION

GENERAL READING GUIDELINES

The document is mainly divided in two parts; a theoretical part that describes the basic principles and a practical part that contains margin calculation examples. The theoretical part has been kept relatively short and many of the mathematical explanations have, in order to facilitate the reading, been moved to one of the appendices.

In the calculation examples, we do not try to exactly replicate the margin calculations performed by the clearing system. The goal is rather to illustrate the basic concepts of the calculations. For exact replication of CFM, please use the risk cubes available through Genium Risk's API, or via interface files.

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Background

Purpose of document

This document describes the NASDAQ OMX CFM methodology applied in order to margin Nordic fixed income instruments. Originally constructed to cater for OTC derivates, it will shortly be possible for clients to elect to margin their entire fixed income portfolio with CFM.

The first part of the document describes the basic margin principles and the second part presents examples on margin calculations. The margin examples will be performed on both naked positions and on hedged positions.

In one of the appendices, please find a short note on how the interface files can be used for exact replication of the margin calculations.

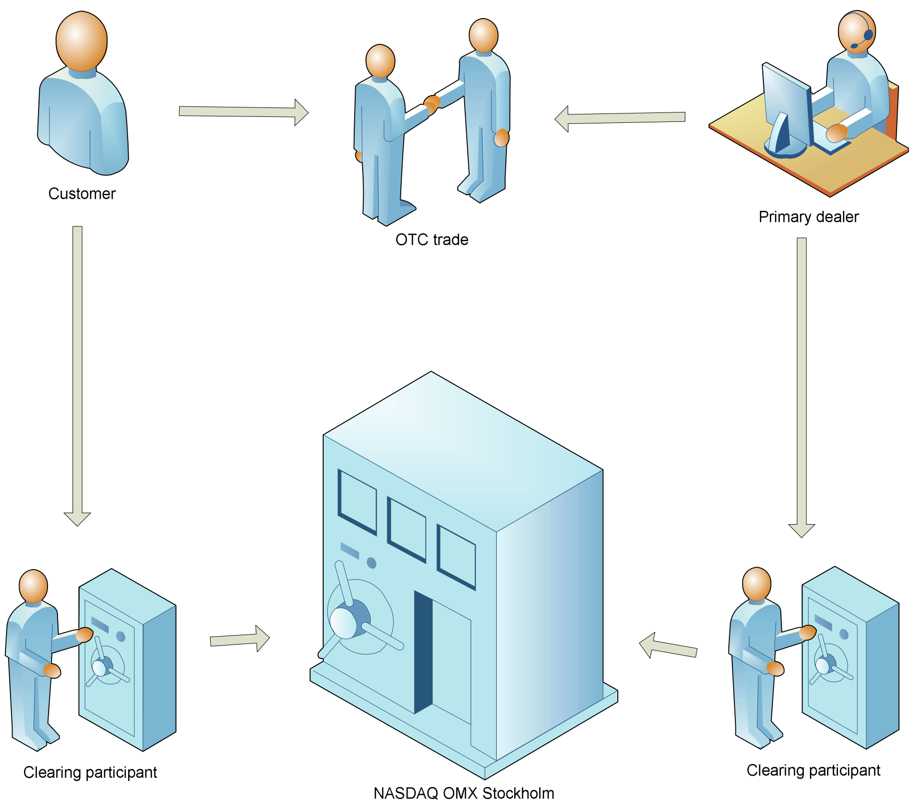
Introduction to clearing

Trading and reporting

- Customers and primary dealers negotiate the terms of the trades off exchange.
- Trades are reported to NOMX via a member firm. All trades are registered in the GENIUM INET clearing system.
- NOMX guarantees that all trades registered in GENIUM INET will be honored.

Transaction flows

Figure: Transaction flows.



Flows between NOMX and the clearing participants

There are two main flows between NOMX and the clearing participants.

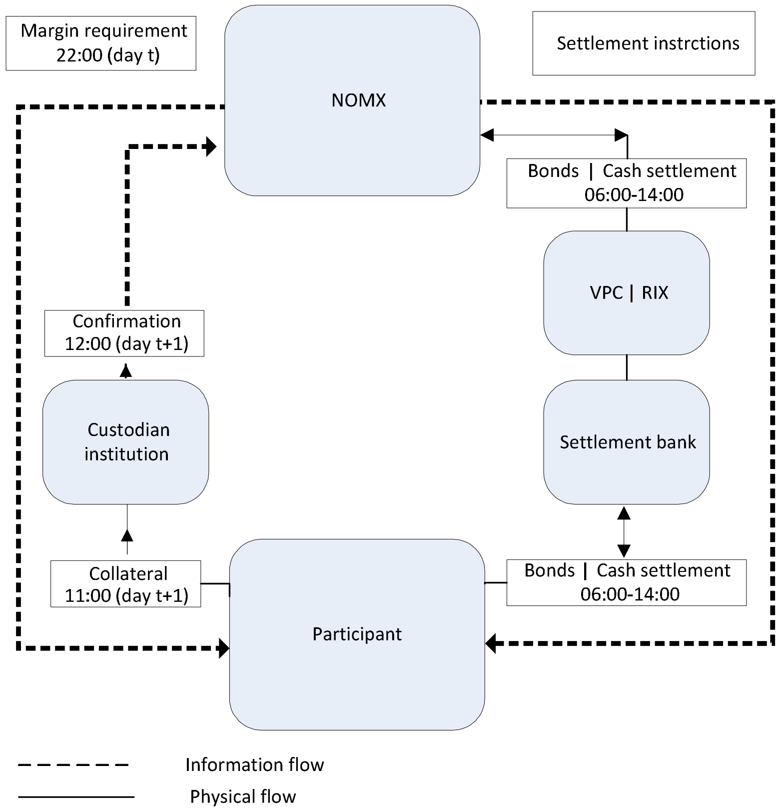
1. Margin – Collateral; NOMX calculates the margin requirement at the end of each trading day (t). The margin requirement becomes available to the clearing participants approximately at CET 22:00 on day t. The clearing participants have to cover their margin requirement with collateral. The clearing participants must have sufficient collateral in place before CET 11:00 on day t+1.

2. Settlement; NOMX provides the clearing participants with settlement instructions. The settlement instructions are normally provided two bank days prior to the settlement day. The cash settlement takes place at CET 11:45 in the Swedish central bank's electronic cash clearing system for banks (RIX) and the

bond delivery takes place between CET 06:00 – 14:00 in the Swedish central securities depository (VPC / Euroclear Sweden AB).

MARGIN AND SETTLEMENT FLOWS

Figure: Margin and settlement flows.



BENEFITS OF CENTRAL CLEARING

Central clearing provides a number of benefits which in the end are increasing market efficiency and decreasing capital employed.

Credit risk reduction is one key benefit when counterparty exposure is switched from the trading counterparty to the clearing house. Another key benefit is the multilateral netting service that the clearing provides. A position taken against a trading counterparty can be closed out by a trade with another trading counterparty. Collateral and margins are pledged on a total portfolio basis rather than on counterparty basis, leading to more efficient capital allocation. The clearing house also allow for netting of positive and negative margins between asset classes which can have significant impact on capital employed.

BENEFITS FOR PRIMARY DEALERS

Market makers and banks benefit from central clearing in a number of areas. Counterparty risk exposure can be significantly reduced and existing counterparty credit lines can be used for other businesses. The bank can trade with new counterparties without having to review that counterpart's credit risk.

Use of a central clearing service will also mean one position per contract against the clearing house instead of multiple counterparty positions.

The bank also benefits from one netted collateral/margining which can have significant impact on capital employment.

One clearing account also means reduced administration when collateral only needs to be pledged once per day[1] against the clearing house instead of multiple pledges in the non cleared market.

BENEFITS FOR INSTITUTIONAL INVESTORS (CUSTOMERS)

Central clearing may provide a simplified access for new market institutional investors since trading with all clearing members can be performed using the same clearing account structure. No counterparty credit lines are needed.

Counterparty risk exposure can be significantly reduced and existing counterparty credit lines can be used for other- or new business.

Using a central clearing service also implies that only one netted collateral/margining amount is needed to be pledged.

BENEFITS FOR AUTHORITIES

Central banks and national debt offices are from time to time active in the financial markets and therefore benefit from reduced counterparty risk exposures as do any other market participant.

Central banks and FSA's etc. also have an interest in central clearing from a financial market stability point of view.

MARGIN REQUIREMENT

The margin requirement is a fundamental part of CCP clearing. In case of a clearing participant's default, it is that participant's margin requirement together with the financial resources of NOMX that ensures that all contracts registered for clearing will be honored.

- NOMX requires margins from all clearing participants, and the margin requirement is calculated with the same risk parameters regardless of the clearing participant's credit rating.
- The margin requirement shall cover the market risk of the positions in the clearing participant's account. NOMX applies a 99.2% confidence level and assumes a liquidation period of two to five days (depending on the instrument) when determining the risk parameters.

Fixed income instruments show very high correlation, and it is important that the margin methodology is able to capture this correlation; otherwise the margin requirements will be too high resulting in an expensive clearing service.

[1] NOMX may perform an intra-day margin call. In this case the affected clearing participant must pledge margins an additional time that day.

Desirable properties of a margin methodology are that it should mirror realistic circumstances, and at the same time be capital efficient. When margining fixed income derivatives it appears natural to utilize the strong intra curve correlation. NOMX CFM (short for NASDAQ OMX CASH FLOW MARGIN) is a yield curve based margin methodology that captures this correlation of fixed income instruments priced against the same curve. NASDAQ OMX has initiated NOMX CFM for REPO transactions and IRS but will shortly include all cleared fixed income products[2].

[2] Danish MBFs will initially continue to be margined using OMS II.

NASDAQ OMX Cash Flow Margin

Executive summary

NASDAQ OMX Cash Flow Margin is a yield curve based margin model. Instead of stressing each instrument's individual price, yield curves are stressed using their first three principal components. All instruments in an account are then evaluated against each stressed yield curve and the margin requirement is given as the combined value of these instruments calculated with the worst of the stressed yield curves.

- **REPO**: A REPO transaction will be treated as a sold/bought spot contract and a corresponding bought/sold forward contract. The spot price will be calculated from the corresponding yield curve
- **IRS**: An interest rate swap will be treated as a series of future cash flows. All swap cash flows will be evaluated against the same curve giving optimal netting benefits between an account's different interest rate swaps.
- **FRA**: A forward rate agreement will be treated as one fixed and one floating cash flow. The floating flow will be forecasted using the swap curve and the contract will be priced using the same curve as for the interest rate swaps
- **Bond-forward:** A bond forward will be priced against the bond's corresponding yield curve. Since the bond forwards are not used for curve construction there will be a small difference between the traded yield of the bond forwards, and the estimated forward yield from the cash flow analysis
- **Options on FRAs and Bond-forwards**: The underlying rate/yield will be stressed in the ways described above, and then an option pricing formula will be applied to determine the stressed NPV of the option.
- **RIBA-future:** A Riksbanks future will be treated as one fixed and one floating cash flow. The floating flow will be forecasted using the RIBA curve. No discounting of cash flows will take place.
- **CIBOR-future:** A CIBOR future will be treated as one fixed and one floating cash flow. The floating flow will be forecasted using the CIBOR curve. No discounting of cash flows will take place.

Yield curves

A key part to NOMX CFM is the ability to calculate the present value of future cash flows. Yield curves are needed in order to do this. This section describes how NOMX obtains the yield curves from instrument prices as well as the method applied in order to stress the curves.

Definition

The yield curve (or more formally the term structure of interest rates) is defined as the relation between the interest rate that lenders require for lending out capital at different maturities. This relationship will of course differ depending on the credit quality of the borrower, and it therefore exist several yield curves in each currency.

BASICS

The yield curve is divided into a short end (all maturities up to two years) and a long end. A common view is that the short end of the yield curve is under the control of the central bank, whereas the long end is much more under the influence of the future inflation anticipated by long term fixed income investors.

Yield curves can be used to extract various types of information:

- **Expectation on future short-term rates:** Although a yield curve may not necessarily reveal all information on investors' view of future short-term rates, it is possible to draw conclusions on this view based on the shape of the yield curves.
- **Probability of default:** The treasury curve, i.e. the yield curve derived from government securities, is in developed markets often assumed to be free from credit risk. The spread between a treasury curve and the yield curve for a financial institution can therefore be used to deduct the market's view of the probability of default for that financial institution.

Underlying price carrier: Since the yield curve is derived from instrument prices it can also be used to price fixed income instruments. This is the most important feature of the yield curve and it is in this sense that NOMX will use the yield curves.

Bootstrapping

Bootstrapping is a methodology that is used to extract the yield curves from the market prices of fixed income instruments.

Basic Definitions

The basic definitions regarding bootstrapping are presented below.

Instruments

A fixed income instrument is defined as a set of rules concerning future cash flows. Prices are quoted on the fixed income instruments and their prices reveal information on the expected return for investing in these instruments. Typical fixed income instruments include bills, bonds, interest rate swaps, and forward rate agreements among others.

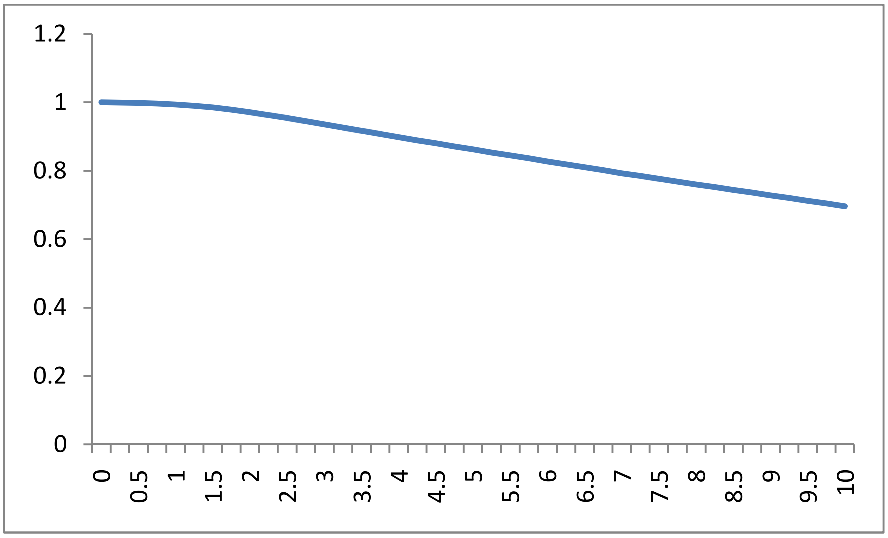
Compounding Frequency and Day Count Convention

NOMX expresses all yield curves as yearly compounded interest rates with day count convention ACT/365.

Discount function

The discount function, $d(0, m_T)$, is defined as the price today of a zero-coupon bond that pays $1 at the value date, T. The discount function is a decreasing function of time to maturity, $m_T = \frac{T - today}{365}$, and by definition it starts at 1.

Figure: Discount function for different time to maturities.

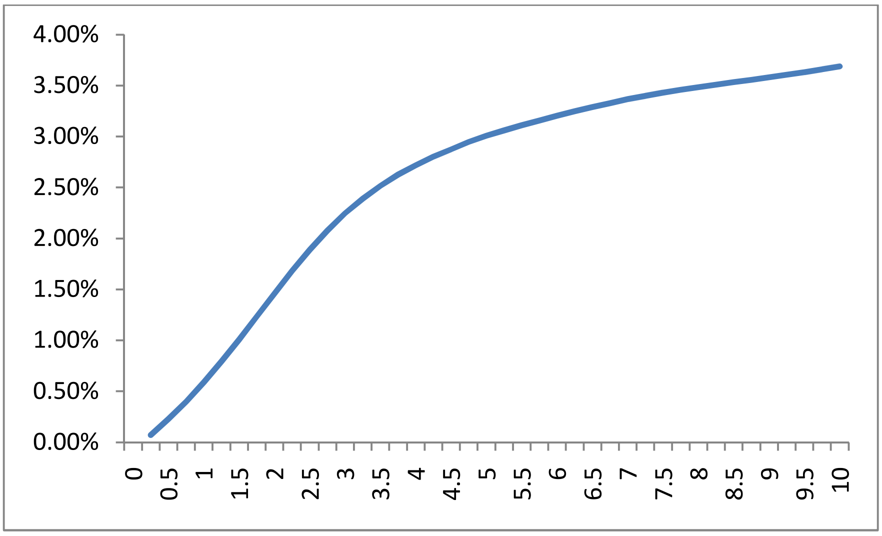


Spot rate

The spot rate, $i(0, m_T)$, is defined as the yearly compounded interest rate for a zero-coupon bond that is traded today, and that matures at the value date, T. Equation (1) relates the spot rate to the discount function.

$$\boldsymbol{i(0, m_T) = \left(\frac{1}{d(0, m_T)}\right)^{\frac{1}{m_T}} - 1} \quad (1)$$

Figure: Spot rate for different time to maturities.



Forward-forward rate

The forward-forward rate, $f(0, m_t, m_T)$, is defined as the yearly compounded implied forward rate on an investment that:

- Is traded today.
- Starts at the settlement date, t.
- Ends at the value date, T.

Equation (2) relates the forward-forward rate to the spot rate.

$$f(0, m_t, m_T) = \left(\frac{(1+i(0,m_T))^{m_T}}{(1+i(0,m_t))^{m_t}}\right)^{\frac{1}{m_T - m_t}} - 1 \qquad 2$$

Bootstrapping procedure

The typical procedure is to bootstrap the discount function. Equation (1) – (2) can then be used to obtain the spot- and the forward-forward rates from the discount function.

NOMX will use the following fixed income instruments as “calibration instruments” in the bootstrapping procedure.

- Bills and bonds will be used to bootstrap the treasury and mortgage curves.
- Deposits, forward rate agreements or interest rate futures, and interest rate swaps will be used to bootstrap the swap curves.
- RIBA futures will be used to bootstrap an implicit RIBA (repo rate) curve.

Please see Appendix I for a detailed description of the bootstrapping methodology applied by NOMX.

PRINCIPAL COMPONENTS ANALYSIS

The present value of a future cash flow, exposed to a given yield curve; will change if the shape of the yield curve changes. A yield curve may change in numerous ways, but there is empirical evidence that the curve's first three principal components express the vast majority of the changes.

This section defines the first three principal components from an economical point of view and further gives a brief overview of how NOMX will use the principal components to stress the yield curves in the margin calculations.

Appendix II gives a more in-depth description of the principal component analysis.

ECONOMICAL DEFINITION OF THE PRINCIPAL COMPONENTS

Principal components (PC) are defined as independent (uncorrelated) moves of the yield curve.

PC1: PARALLEL SHIFT

For a yield curve the first PC is a parallel shift of the entire curve. This PC usually explains 75%-85% of the curve's historical movement. This is also quite understandable, that economic factors that changes cause the interest rate market as a whole to increase or decrease.

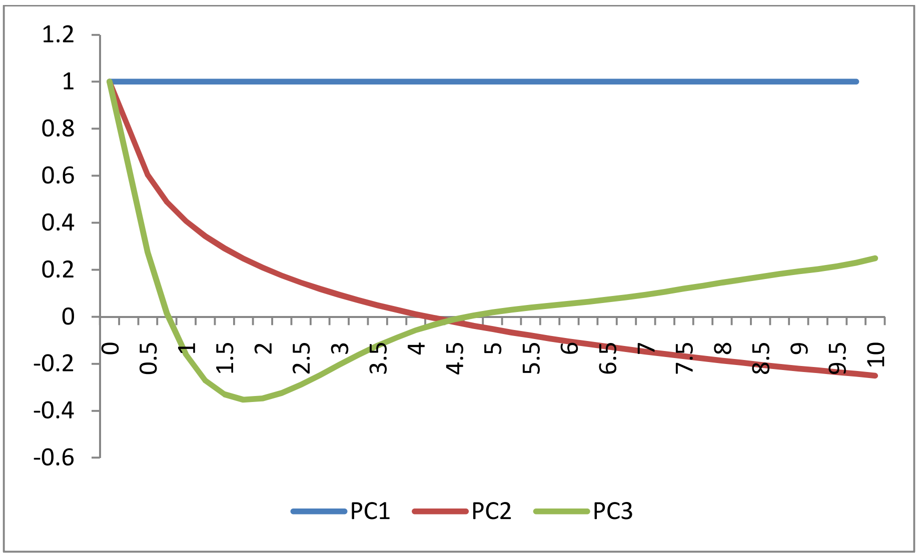
PC2: CHANGE IN SLOPE

The second PC is a change to the slope of the curve. The long end goes up while the short end goes down or vice versa. This PC usually explains 10%-15% of the curve's historical movement.

PC3: CHANGE IN CURVATURE

The third PC is a change to the curvature of the curve. The short and the long end increase while the mid section decrease or vice versa. This PC usually explains 3%-5% of the curve's historical movement.

Figure: A yield curve's first three principal components.



Stressing a curve with its principal components

A yield curve's principal components are by definition uncorrelated. The first three principal components explain the majority of the variance which implies that a linear combination of the principal components can be used to simulate curve changes with high accuracy[3].

NOMX will, on a quarterly basis, evaluate and, if needed, update each yield curve's first three principal components together with a risk parameter that decides how much of this principal component that will be used to simulate the stressed curves.

A risk parameter of 22 basis points in PC1 will for example imply that the curve will be stressed with a parallel shift of 22 basis points upwards and downwards.

Figure: Stressing a curve with its first PC i.e. by different levels of parallel shifts.

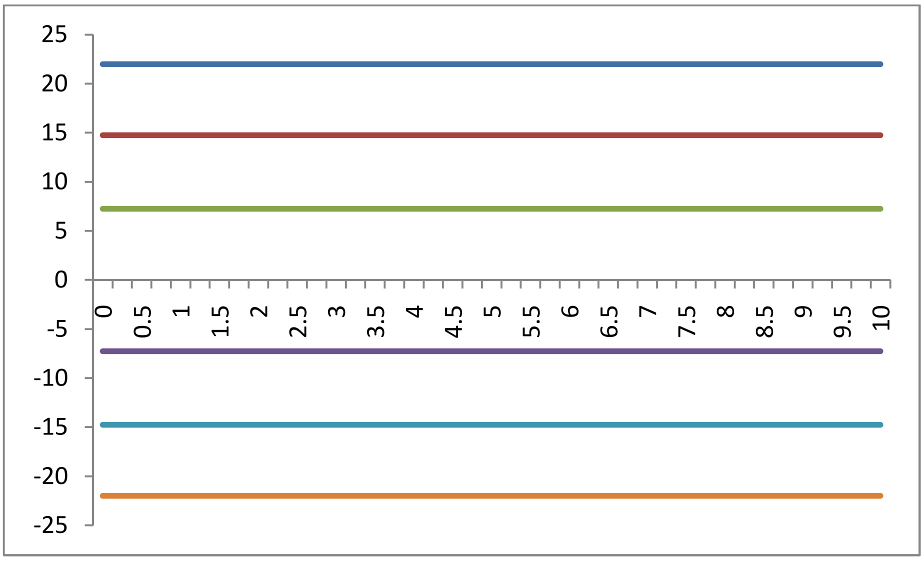
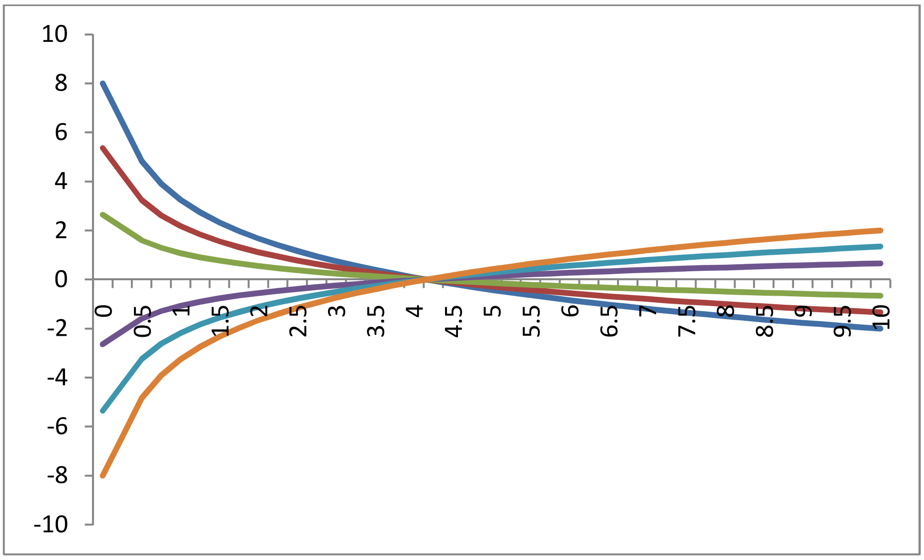
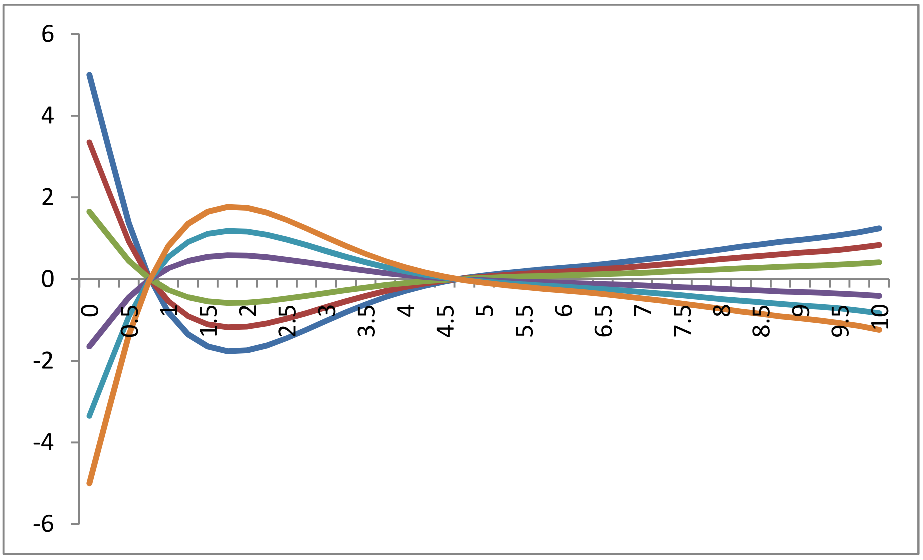


Figure: Stressing a curve with its second PC i.e. by different levels of slope changes.



[3] This statement has been validated with back testing calculations performed by NOMX.

Figure: Stressing a curve with its third PC i.e. by different levels of curvature changes.



NOMX will on each trading day, t, bootstrap official spot curves ($Curve_t$). These curves will be the basis to all stressed curves. Equation (3) will be used to simulate the stressed curves from the official curves. NOMX defines the yield curves and their principal components as vectors. Equation (3) is therefore a vector equation were each element is handled separately. The margin calculation examples in the end of this document describe this process in more detail.

$$\overline{Curve}_{Stressed} = \overline{Curve}_t + a \cdot \overline{PC1} + b \cdot \overline{PC2} + c \cdot \overline{PC3} \qquad 3$$

a, b and c will range between ± each principal component's risk parameter.

Applying a Buy & Sell Spread

NOMX has the ability to apply a spread to the curves used for margining. Depending on the instrument being priced, this spread will be applied in a different step in the process.

For derivatives with bonds as underlying instruments the spread will be applied when discounting the fixed cash flows stemming from the bond. This is the case for repos and bond forwards.

For derivatives with floating cash flows the spread will be applied when forecasting the sizes of these cash flows. This is the case for swaps, forward rate agreements, RIBA futures, STIBOR-futures and CIBOR-futures.

Calculation Principles

At the core of NOMX CFM are the cash flows of the instruments. For all instruments, an important step in the calculation is to identify these flows, and categorize them as floating or fixed. They are then inserted in a cash flow table.

Subsequently the cash flows are used in various ways for different instruments. Below we describe these procedures that in the end lead to a calculated margin.

Definition of cash flow tables

A cash flow table is an object with the following properties.

- Curve exposure; a reference to the yield curve that the cash flows in this table are exposed to. This is the curve that will be used when discounting these cash flows and when determining the size of the floating cash flows.
- Currency; each column in the cash flow table represent the currency of the cash flows.
- Value date; each row in the cash flow table represent the value date of a cash flow.

Figure: Example of a treasury cash flow table.

Value date	SEK
2010-03-15	52 500 000
…	…
2011-03-15	1 052 500 000

Break up algorithms

REPO

Definitions

Standard	=	Defines if this is a “classic REPO” or a “buy and sell back”.
T	=	Trade date.
t_s	=	Start date.
t_e	=	End date.
t_m	=	Maturity date of the underlying bond.
t_c	=	Date of the underlying bond’s last coupon payment.
$d_{i,j}$	=	Number of days between dates t_i and t_j (30E).
Q	=	Quantity.
N	=	Nominal amount of the underlying bond.
C	=	Coupon of the underlying bond.
Side	=	$\begin{cases} 1\ for\ a\ REPO. \\ -1\ for\ a\ reversed\ REPO. \end{cases}$
CP_t	=	Underlying bond’s clean price at time t.
r_{repo}	=	Contracted repo rate.
C_i	=	Underlying bond’s payment at value date t_i.
X_s	=	Start consideration.
X_e	=	End consideration.
Row_i	=	Cash flow table value for value date t_i.

Formulas

Start consideration

Equation (4) is used to calculate the start consideration for both a classic REPO and for a buy and sell back.

$$X_s = \left(CP + C \cdot \frac{d_{t_c,t_s}}{360}\right) \cdot \frac{N}{100} \cdot Q \qquad 4$$

Note that if ex-coupon date has passed, the accrued interest will be negative

End consideration

Classic repo

Equation (5) is used to calculate the end consideration for a classic REPO.

$$X_e = X_s \cdot \left(1 + r_{repo} \cdot \frac{d_{s,e}}{360}\right) \qquad 5$$

Buy and sell back

Equation (6) is used to calculate the end consideration for a buy and sell back.

$$X_e = X_s \cdot \left(1 + r_{repo} \cdot \frac{d_{s,e}}{360}\right) - C_i \cdot \left(1 + r_{repo} \cdot \frac{d_{i,e}}{360}\right) \qquad 6$$

It is only the underlying bond's payments, C_i, that are on value dates, t_i, in the interval [t_s+5, t_e+5] that should be included in Equation (6).

Classic repo

Equation (7) - (8) will be used to insert the start and end considerations into the start and end consideration cash flow table.

$$Row_s = Side \cdot X_s \qquad 7$$

$$Row_e = -Side \cdot X_e \qquad 8$$

Equation (9) will be used to insert the underlying bond's payments, C_i, that are on value dates t_i in the interval [t_s+5, t_e+5] into the start and end consideration cash flow table.

$$Row_i = Side \cdot C_i \qquad 9$$

Buy and sell back

Equation (7) – (8) will be used to insert the start and end considerations into the start and end consideration cash flow table.

Bond cash flow table

The underlying bond will be exchanged two times in a REPO transaction, on the start date and on the end date.

Start date

Classic repo

Equation (10) will be used to insert the cash flows originating from the underlying bond that is exchanged on the start date into the bond cash flow table.

$$\boldsymbol{Row_i = -Side \cdot Q \cdot C_i \, for \, all \, C_i \, that \, lay \, inside[t_e + 5, t_m]} \qquad \mathbf{10}$$

Buy and sell back

Equation (11) will be used to insert the cash flows originating from the underlying bond that is exchanged on the start date into the bond cash flow table.

$$\boldsymbol{Row_i = -Side \cdot Q \cdot C_i \, for \, all \, C_i \, that \, lay \, inside[t_s + 5, t_m]} \qquad \mathbf{11}$$

End date

Equation (12) will be used to insert the cash flows originating from the underlying bond that is exchanged on the end date into the cash flow table.

$$\boldsymbol{Row_i = Side \cdot Q \cdot C_i \, for \, all \, C_i \, that \, lay \, inside[t_e + 5, t_m]} \qquad \mathbf{12}$$

Example

Considerer a one week REPO in RGKB1045.

Standard	=	Buy and sell back.
t	=	2009-11-02.
t_s	=	2009-11-04.
t_e	=	2009-11-11.
t_m	=	2011-03-15.
t_c	=	2009-03-15.
Q	=	1 000.
N	=	SEK 1 000 000.
C	=	5,25.
Side	=	1.
CP	=	105,89.
r_{repo}	=	0,25%.
C_i	=	see table below

Payment	52 500	1 052 500
Date	2010-03-15	2011-03-15

Start consideration

Equation (4) is used to calculate the start consideration. It is 229 days between 2009-03-15 and 2009-11-04 in a 30E convention.

$$X_s = \left(105{,}89 + 5{,}25 \cdot \frac{229}{360}\right) \cdot \frac{1\,000\,000}{100} \cdot 1000 = SEK\ 1\,092\,295\,833$$

End consideration

Equation (6) is used to calculate the end consideration.

$$X_e = 1\,092\,295\,833 \cdot \left(1 + 0{,}25\% \cdot \frac{7}{360}\right) = SEK\ 1\,092\,348\,931$$

This would result in the following cash flow table.

START AND END CONSIDERATION CASH FLOW TABLE (EXPOSED TO THE TREASURY CURVE)

Equation (8) – (9) is used to insert the start and end considerations into the start and end consideration cash flow table.

Value date	SEK
2009-11-04	1 · 1 092 295 833 = 1 092 295 833
2009-11-11	-1 · 1 092 348 931 = -1 092 348 931

TREASURY CASH FLOW TABLE

Before the start date of the REPO, the underlying bond will not have been exchanged, and since the underlying bond does not pay any coupons in the interval [t_s+5, t_e+5]the cash flows from Equation (11) and Equation (12) will cancel out each other. The bond cash flow table will therefore be empty until after the start date of the REPO.

Interest rate swaps

The cash flows of a fixed for floating interest rate swap are exposed to the swap curve. Equations (13) - (16) are used to break up a fixed for floating interest rate swap.

Definitions

t	=	Trade date.
t_s	=	Start date.
t_e	=	End date.
Q	=	Quantity.
N	=	Principal amount.
Side	=	$\begin{cases} 1 \; if \; the \; swap \; is \; bought. \\ -1 \; if \; the \; swap \; is \; sold. \end{cases}$
$r_{i,i+1}$	=	Forward-forward swap rate valid from t_i to t_{i+1}.
$d_{i,i+1}$	=	Number of days in the floating interest rate period between value dates t_i and t_{i+1} (ACT).
r_{fl}	=	First floating interest rate (this is known at the time when the swap is entered).
r_f	=	Fixed contracted rate of the interest rate swap.
$d_{f,i,i+1}$	=	Number of days in the fixed interest rate period between value dates t_i and t_{i+1} (30E).
Row_i	=	Cash flow table value for value date t_i.

Equations

Floating cash flows

$$\boldsymbol{Row_{i+1} = Side \cdot Q \cdot N \cdot r_{i,i+1} \cdot \frac{d_{i,i+1}}{360}} \qquad \mathbf{13}$$

The forward-forward rate, $r_{i,i+1}$, is a function of the swap spot rate. This implies that $r_{i,i+1}$ will be updated each time the swap spot rate is updated. A floating cash flow will therefore be updated for each stressed curve that is used in the margin calculations.

It should be noted that $r_{i,i+1}$ does not use the same compounding frequency compared to the forward-forward rate, $f(0, m_i, m_{i+1})$, defined in Equation (2). Equation (14) relates the two forward rates.

$$\boldsymbol{r_{i,i+1} = \frac{360}{d_{i,i+1}} \cdot \left((1 + f(0, m_i, m_{i+1}))^{m_{i+1} - m_i} - 1 \right)} \qquad \mathbf{14}$$

Fixed cash flows

First floating interest rate

The first floating interest rate is known at the time when the swap is entered. The first floating cash flow is therefore in reality a fixed cash flow.

$$\boldsymbol{Row_1 = Side \cdot Q \cdot N \cdot r_{fl} \cdot \frac{d_{0,1}}{360}} \qquad \mathbf{15}$$

Fixed contracted interest rate

$$\boldsymbol{Row_{i+1} = -Side \cdot Q \cdot N \cdot r_f \cdot \frac{d_{f,i,i+1}}{360}} \qquad \mathbf{16}$$

Example

Consider a sold 3Y plain vanilla SEK fixed for floating interest rate swap.

t	=	2009-11-02
t_s	=	2009-11-04.
t_e	=	2012-11-04.
Q	=	5
N	=	SEK 1 000 000
Side	=	-1
r_{fl}	=	0,3%
r_f	=	1,7%

This would result in the following cash flow table. It should be noted that since the first floating cash flow is in fact a fixed cash flow it is moved to the fixed side. It should further be noted that the floating cash flows will be updated when the swap spot curve changes.

Swap cash flow table

Value date	SEK (floating)	SEK (fixed)
2010-02-04		$-1 \cdot 5 \cdot 1\,000\,000 \cdot 0{,}3\% \cdot \frac{92}{360}$
2010-05-04	$-1 \cdot 5 \cdot 1\,000\,000 \cdot r_{1,2} \cdot \frac{89}{360}$	
2010-08-04	$-1 \cdot 5 \cdot 1\,000\,000 \cdot r_{2,3} \cdot \frac{92}{360}$	
2010-11-04	$-1 \cdot 5 \cdot 1\,000\,000 \cdot r_{3,4} \cdot \frac{92}{360}$	$1 \cdot 5 \cdot 1\,000\,000 \cdot 1{,}7\% \cdot \frac{360}{360}$
2011-02-04	$-1 \cdot 5 \cdot 1\,000\,000 \cdot r_{4,5} \cdot \frac{92}{360}$	
2011-05-04	$-1 \cdot 5 \cdot 1\,000\,000 \cdot r_{5,6} \cdot \frac{89}{360}$	
2011-08-04	$-1 \cdot 5 \cdot 1\,000\,000 \cdot r_{6,7} \cdot \frac{92}{360}$	
2011-11-04	$-1 \cdot 5 \cdot 1\,000\,000 \cdot r_{7,8} \cdot \frac{92}{360}$	$1 \cdot 5 \cdot 1\,000\,000 \cdot 1{,}7\% \cdot \frac{360}{360}$
2012-02-06	$-1 \cdot 5 \cdot 1\,000\,000 \cdot r_{8,9} \cdot \frac{94}{360}$	
2012-05-04	$-1 \cdot 5 \cdot 1\,000\,000 \cdot r_{9,10} \cdot \frac{88}{360}$	
2012-08-06	$-1 \cdot 5 \cdot 1\,000\,000 \cdot r_{10,11} \cdot \frac{92}{360}$	
2012-11-05	$-1 \cdot 5 \cdot 1\,000\,000 \cdot r_{11,12} \cdot \frac{92}{360}$	$1 \cdot 5 \cdot 1\,000\,000 \cdot 1{,}7\% \cdot \frac{360}{360}$

FORWARD RATE AGREEMENTS

A forward rate agreement (FRA) is a forward contract on a fictive forward loan i.e. a view on the future 3MSTIBOR rate. There is no delivery of the underlying loan amount. Only a cash amount corresponding to the interest rate difference between agreed interest rate and the fixing rate will be paid. The buyer of the contract is a fictitious borrower who assumes the obligation to pay the difference between the agreed interest rate and the fixing rate to the seller on condition that the agreed interest rate is higher. If the agreed interest rate is lower than the fixing rate, the buyer is paid the interest rate amount by the seller. The amount is valued three months after the expiration of the FRA contract. However, the actual payment is settled on the settlement day of the FRA contract three months earlier. This means that the valued amount needs to be discounted to the settlement day of the FRA contract.

Equations (17) – (18) are used to insert a FRA into the FRA cash flow table.

DEFINITIONS

t	=	Trade date.
t_m	=	Maturity date of the FRA.
Q	=	Quantity.
N	=	Principal amount of the fictive loan.
Side	=	$\begin{cases} 1 \text{ } if \text{ } the \text{ } FRA \text{ } is \text{ } bought. \\ -1 \text{ } if \text{ } the \text{ } FRA \text{ } is \text{ } sold. \end{cases}$
$r_{i,i+1}$	=	Forward-forward swap rate between t_i and t_{i+1}.
$d_{i,i+1}$	=	Number of days in the floating interest rate period between value dates t_i and t_{i+1} (30E).
r_c	=	Contracted rate of the FRA.
$PnL_{FRA}(r_{i,i+1},r_c)$	=	Profit and loss of a FRA contract given a forward-forward rate, $r_{i,i+1}$, and a contracted rate, r_c.
Row_m	=	Cash flow table value for value date t_m.

FORMULAS

It should be noted that $r_{i,i+1}$ is defined with a different compounding frequency compared to $f(0, m_i, m_{i+1})$. Equation (14) relates the two forward-forward rates.

$$\boldsymbol{PnL_{FRA}(r_{i,i+1}, r_c) = Side \cdot Q \cdot N \cdot (r_{i,i+1} - r_c) \cdot \frac{d_{i,i+1}}{360}} \quad \textbf{17}$$

$$\boldsymbol{Row_m = \frac{PnL_{FRA}(r_{m,m+1}, r_c)}{(1 + r_{m,m+1} * \frac{d_{i,i+1}}{360})}} \quad 18$$

Example

Consider 100 bought FRA09X contract.

t	=	2009-11-02
t_m	=	2009-12-16
Q	=	100
N	=	SEK 1 000 000
Side	=	1
r_c	=	0,4%

This would result in the following FRA cash flow table. The FRA cash flow is a floating cash flow and hence it is updated as the swap spot curve changes.

FRA cash flow table (exposed to the swap curve)

Value date	SEK (floating)
2009-12-17	$\dfrac{PnL_{FRA}(r_{2009-12-16,2010-03-17}, r_c)}{(1 + r_{2009-12-16,2010-03-17} * \frac{d_{i,i+1}}{360})}$

Options on Forward Rate Agreements

The pricing of the FRA options builds on the same methodology used to price the FRAs. The method for estimating the forward rate is exactly the same. Given an estimated rate (r_{est}), the calculation of the NPV for a specific option is given by the following calculations.

Definitions

Q	=	Quantity of underlying contracts
N	=	Nominal contract size
T	=	Time to expiry
d_{FRA}	=	Length of underlying FRA, measured in days
r_S	=	Strike expressed as forward yield
r_{est}	=	Forward yield estimated from the curve
σ_r	=	Yield volatility
p	=	Value of option, expressed in yield
BPV	=	Basis point value of underlying FRA

Formulas

The strike rate, the estimated rate given by the curve, the rate volatility and the time to expiry are entered into a binomial option pricing formula. The result from the binomial pricing formula is the price of the option expressed in yield. In order to convert this premium to a cash measure, the BPV of the underlying FRA is used. For the FRA options a constant BPV per contract, as defined below, is used. That is, no convexity effects are taken into account.

$$p = \mathrm{Binomial}(r_S, r_{est}, \sigma_r, T) \qquad 19$$

$$BPV = \frac{d_{FRA}}{360} \Big/ 10000 \qquad 20$$

$$NPV = BPV * p * 100 * Q * N \qquad 21$$

RIBA FUTURE

A riba future is a daily cash-settled contract on the Riksbank's repo rate. The contract base is a fictious loan extending between two consecutive IMM-dates, and the price is quoted as a compound interest. The final fix of each future is determined by the repo rate between the IMM-date of the contract's end month and the preceding IMM-date. Therefore, during the last three months of a contract's life, the price risk is gradually decreasing as the final fix is increasingly made known. CFM will pick up this feature through taking into consideration the historic repo-rate when constructing and stressing the curves. In CFM, the RIBA futures will be margined using a designated riba curve, built from the prices on the riba contracts.

Equations (22) – (23) are used to insert a RIBA into the RIBA cash flow table.

DEFINITIONS

t_m	=	Maturity date of the RIBA i.e. the IMM-date of the contract's end month.
t_{m-1}	=	Preceding IMM-date.
t_{fix}	=	The highest date to which the Riksbank's repo-rate is known. Note that this can be a future date.
Q	=	Quantity.
N	=	Principal amount of the fictive loan.
Side	=	$\begin{cases} 1 \text{ } if \text{ } the \text{ } RIBA \text{ } is \text{ } bought. \\ -1 \text{ } if \text{ } the \text{ } RIBA \text{ } is \text{ } sold. \end{cases}$
$r_{i,i+1}$	=	Forward-forward repo rate between t_i and t_{i+1}.
$R_{i,i+1}$	=	Historic repo rate between t_i and t_{i+1} ,expressed as a compounded rate.
r_{first}	=	Estimated rate for the first RIBA contract.
$d_{i,i+1}$	=	Number of days in the floating interest rate period between value dates t_i and t_{i+1} (ACTUAL).
r_c	=	Contracted rate of the RIBA i.e. the last fixing of the RIBA.
$PnL_{FRA}(r_{i,i+1},r_c)$	=	Profit and loss of a RIBA contract given a forward-forward rate, $r_{i,i+1}$, and a contracted rate, r_c.

FORMULAS

For all contracts except the front contract, the P/L is calculated in a straight forward way.

$$\boldsymbol{PnL_{RIBA}(r_{m-1,m}, r_c) = Side \cdot Q \cdot N \cdot (r_{m-1,m} - r_c) \cdot \frac{d_{m-1,m}}{360}} \qquad \mathbf{22}$$

For the front contract, we will take into consideration the historic repo rate from the preceding IMM-date up to the highest date to which the Riksbank's repo rate has been determined. We use this information to calculate an estimated rate for the first RIBA contract. Then the P/L can be calculated as above.

$$\mathbf{r_{first}} = \left(\left(1 + R_{m-1,fix} \cdot \frac{d_{m-1,fix}}{360}\right) \cdot \left(1 + r_{fix,m} \cdot \frac{d_{fix,m}}{360}\right) - 1\right) \cdot \frac{360}{d_{m-1,m}} \qquad 23$$

$$PnL_{RIBA}\left(r_{first}, r_c\right) = Side \cdot Q \cdot N \cdot \left(r_{first} - r_c\right) \cdot \frac{d_{m-1,m}}{360} \qquad 24$$

As the RIBA is a futures contract, the P/L does not need to be added into a cash flow table in order to calculate the NPV.

Example 1

For value date 2011-09-05, consider 100 bought RIBAZ1 contract

RIBAZ1.

t_m	=	2011-12-21
t_{m-1}	=	2011-09-21
Q	=	100
N	=	SEK 1 000 000
Side	=	1
r_c	=	2,04%

Since in this example, the start date of the underlying IMM-period is in the future, we only have to take the estimated forward repo rate into consideration. There are 91 days in the underlying period. Given a RIBA curve, the P/L of this RIBA future is given by the following formula.

$$PnL_{RIBA}\left(r_{2011-09-21,2011-12-21}, 2{,}04\%\right) =$$

$$1 \cdot 100 \cdot 1000\,000 \cdot (r_{2011-09-21,2011-12-21} - 2.04\%) \cdot \frac{91}{360}$$

Example 2

For value date 2011-09-05, consider 100 bought RIBAU1 contract.

RIBAU1

t_m	=	2011-09-21
t_{m-1}	=	2011-06-15
t_{fix}	=	2011-09-07
Q	=	100
N	=	SEK 1 000 000
Side	=	1
r_c	=	1,96%

Since in this example, the start date of the underlying IMM-period is in the past, we have to take the historic repo rate into account. For the first three weeks (from 2011-06-15 to 2011-07-06) the weekly repo rate was 1,75%, and for the remainder of the period until 2011-09-07 it was 2%, resulting in a compound average rate of 1,94%. There are 98 days in the underlying period, and for the first 84 of these the repo rate is known. Given a RIBA curve, the P/L of this RIBA future is given by the following calculation in two steps.

$$\mathbf{r_{first}} = \left(\left(1 + 1,94\% \cdot \frac{84}{360}\right) \cdot \left(1 + r_{2011-09-07,2011-09-21} \cdot \frac{14}{360}\right) - 1\right) \cdot \frac{360}{98}$$

$$PnL_{RIBA}\left(r_{first}, 1,96\%\right) = 1 \cdot 100 \cdot 1\,000\,000 \cdot \left(r_{first} - 1,96\%\right) \cdot \frac{98}{360}$$

CIBOR/STIBOR FUTURE

NOMX offers clearing of interest rate futures with the 3M Deposits of CIBOR and STIBOR as underlyings. These futures are quoted as [100-yield], which means that their P/L dynamics are similar to that of cash bonds. In contrast to the other cleared derivatives with single period forward rates as underlyings (RIBA futures and FRAs), an increase in the estimated underlying rate results in a negative P/L. For example, a long position in a STIBOR future can be hedged by a long position in a FRA for the same period. The CIBOR/STIBOR Futures always have an underlying period of 90 days, independently of the actual number of days between the IMM-days.

DEFINITIONS

t	=	Trade date.
t_m	=	Maturity date.
Q	=	Quantity.
N	=	Principal amount of the fictive loan.
Side	=	$\begin{cases} 1 \; if \; the \; future \; is \; bought. \\ -1 \; if \; the \; future \; is \; sold. \end{cases}$
$r_{i,i+1}$	=	Forward-forward swap rate between t_i and t_{i+1}.
P_c	=	Daily fix
r_c	=	Contracted rate of the FRACIBOR/STIBOR Future.
Row_m	=	Cash flow table value for value date t_m.

The daily fix is quoted in price (100-median value in yield) i.e. (100 - r). The cash flows are decided by the formulas:

$$\boldsymbol{r_c = 100 - P_c} \qquad \mathbf{25}$$

$$\boldsymbol{PnL_{STIBOR}(r_{m,m+1}, r_c) = Side \cdot Q \cdot N \cdot (r_c - \; r_{m,m+1}) \cdot \frac{90}{360}} \qquad \mathbf{26}$$

As we are here dealing with futures contracts, the P/L doesn't need to be added to any cash flow table for discounting purposes.

EXAMPLE 1

For value date 2011-09-02, consider 100 sold 3MSTIBZ1 contracts.

3MSTIBZ1

t	=	2011-09-02.
t_m	=	2011-12-21.
Q	=	100.
N	=	1 000 000.
Side	=	-1.
$d_{1,2}$	=	90.
P_c	=	97,559
r_c	=	2,441%

$$PnL_{3MSTIBZ1}\left(r_{2011-12-21,2012-03-21}, 2{,}441\%\right) =$$

$$-1 \cdot 100 \cdot 1000\,000 \cdot (2{,}441\% - \; r_{2011-12-21,2012-03-21}) \cdot \frac{90}{360}$$

Bond forwards

NASDAQ OMX has two types of bond forwards; synthetic and non synthetic. The non synthetic bond contract has remaining maturity and coupon rate equal to the deliverable bond in each series. The synthetic bond forward contracts have a maturity of two, five or ten years and a fixed annual coupon rate.

It should be noted that the NPV is calculated from a yield curve built up using prices on cash bonds. The bond forward contracts are not used as calibration instruments and thus the unstressed NPV will slightly deviate from the market value. However, the market value presented in margin reports for the bond forwards will be calculated from equation (19) based on the difference between the traded price (r) and today's fixed price (r_t).

The synthetic bond forward contract is traded on the forward yield of the deliverable bond, but the P/L is calculated using the characteristics of the synthetic bond. Using CFM to calculate margin for these contracts therefore requires some additional steps compared to the usual cash flow forecasting and discounting used for most other interest rate derivatives. In short, the cash flows of the synthetic bond forward will be forward valued, not by using the yield curve, but by using the forward yield to maturity of the deliverable bond as implied by the yield curve.

Monthly cash settlement

The fixed income forwards are hybrid futures/forward contracts. The hybrid style arises from the fact that the contract is not settled daily; instead a monthly cash settlement is carried out. This means that margin calculations for fixed income forwards must consider the trade yield or the previous month fixing yield depending on if the trade was carried out during the month or previous to the last monthly cash settlement. At the end of each month the accrued profit and losses on all fixed income forwards contracts are settled at a closing yield for that month, the monthly fixing yield. This effectively revalues open positions to the monthly fixing yield, which is the yield used when calculating subsequent margin requirements.

Definitions

t	=	Day t
n	=	Outstanding coupons
N	=	Nominal value
C	=	Coupon rate
Q	=	Number of contracts
r	=	Yield (contracted yield or the last monthly cash settlement yield, whichever applicable)
r_t	=	Fixing yield at day t
d	=	Number of days between the contract's settlement date (IMM) and next coupon payment (30E)
d_e	=	The forward contract's expiration date
d_{sett}	=	The forward contract's settlement day
d_c	=	Next coupon date
C_i	=	Underlying bond's payment at value date t_i

Formulas

Equation (19) is used to convert a price quoted in yield to a price in money

$$\mathbf{P_{bond}(r) = N \cdot \frac{\left(\frac{C}{r}\cdot((1+r)^{n}-1)+1\right)}{\left((1+r)^{\left(\frac{d}{360}+n-1\right)}\right)}} \qquad \mathbf{27}$$

The first cash flow is decided by the trade price (contracted yield) and will be executed on the IMM date, usually t+4 for Swedish bond forwards. All upcoming coupons after the settlement date of the delivery, plus the nominal at end should also be considered as cash flows[4].

Equation (20) is used for synthetic forward contracts to calculate the forward price quoted in yield of the deliverable bond. The forward yield to maturity, y, is the solution to the following equation.

$$\frac{\text{Cash flow}_i}{(1+f(0,m,m_i))^{t_i}} + \frac{\text{Cash flow}_{i+1}}{(1+f(0,m,m_{i+1}))^{t_{i+1}}} + \cdots + \frac{\text{Cash flow}_{i+n}}{(1+f(0,m,m_{i+n}))^{t_{i+n}}} = \frac{\text{Cash flow}_i}{(1+y)^{t_i}} + \frac{\text{Cash flow}_{i+1}}{(1+y)^{t_{i+1}}} + \cdots + \frac{\text{Cash flow}_{i+n}}{(1+y)^{t_{i+n}}} \qquad \mathbf{28}$$

where the day count convention is 30E.

Example non synthetic bond forward

Consider the below portfolio of 100 sold NBHYP2 (2-year Nordbanken Hypotek Bond) contracts

t	=	2011-02-15
n	=	3
N	=	SEK 1 000 000
C	=	4,25.
Q	=	100
r	=	3,50%
r_t	=	3,55%
d		93
d_e	=	2011-03-10
d_{sett}	=	2011-03-16
d_c	=	2011-06-19
C_i	=	

Payment	42 500	42 500	1 042 500
Date	2011-06-19	2012-06-19	2013-06-19

Equation (19) is used to calculate the trade price. It is 93 days between 2011-03-16 and 2011-06-19 in a 30E convention.

[4] If the deliverable bond has a coupon payment less than 5 days from the final settlement of the forward contract, then the original owner of the deliverable bond will receive the coupon payment. In this scenario one coupon payment shall be removed from the mark to market amount.

$$P_{bond}(3{,}50\%) = 1000\,000 \cdot \frac{\left(\frac{4{,}25\%}{3{,}50\%} \cdot ((1+3{,}50\%)^3 - 1) + 1\right)}{\left((1+3{,}50\%)^{\left(\frac{93}{360}+3-1\right)}\right)} = 1\,047\,398$$

This would result in the following cash flow table.

Value date	SEK
2011-03-16	-100 · 1 046 215 = -104 739 800
2011-06-19	100 · 42 500 = 4 250 000
2012-06-19	100 · 42 500 = 4 250 000
2013-06-19	100 · (42 500 + 1000 000) = 104 250 000

EXAMPLE SYNTHETIC BOND FORWARD

Consider the below portfolio of 100 sold R2RR (government bond) contracts. The forward contract is traded on the forward yield of the deliverable bond and thus the bond forward will be valued by using the forward yield to maturity of the deliverable bond as implied by the yield curve. The deliverable bond for R2RR is RGKB1041 with maturity 2014-05-05 and a coupon rate of 6,75%.

t = 2011-03-02
n = 3
N = SEK 1 000 000
C = 6,75.
Q = -100
r = 2,99%
r_t = 2,99%
d = 320
d_e = 2011-06-09
d_{sett} = 2011-06-15
d_c = 2012-05-05
C_i =

Payment	67 500	67 500	1 067 500
Date	2012-05-05	2013-05-05	2014-05-05

Equation (19) is used to calculate the trade price. It is 320 days between 2011-06-15 and 2012-05-05 in a 30E convention.

$$P_{bond}(2{,}99\%) = 1000\,000 \cdot \frac{\left(\frac{6{,}75\%}{2{,}99\%} \cdot ((1+2{,}99\%)^3 - 1) + 1\right)}{\left((1+2{,}99\%)^{\left(\frac{320}{360}+3-1\right)}\right)} = 1\,110\,004$$

This would result in the following cash flow table.

Value date	SEK
2011-06-15	100 · 1 110 004 = 111 000 400
2012-05-05	-100 · 67 500 = -6 750 000
2013-05-05	-100 · 67 500 = -6 750 000
2014-05-05	-100 · (67 500 + 1000 000) = -106 750 000

The forward-forward rate $f(0, m, m_i)$ will be derived from the appropriate curve, in this example the cash flows are exposed to the treasury curve. The forward-forward rates and the above cash flows are inserted into Equation (20) to calculate the forward price quoted in yield of the deliverable bond (r_{est}). Equation (19) will then be used to determine a forward price in money of the synthetic bond forward.

Options on Bond forwards

The pricing of the Bond forward options builds on the same methodology used to price the Bond forwards. The method for estimating the forward yield is exactly the same. Given an estimated yield (r_{est}), the calculation of the NPV for a specific option is given by the following calculations.

Definitions

Q	=	Quantity of underlying contracts
N	=	Nominal contract size
T	=	Time to expiry
r_S	=	Strike expressed as forward yield
r_{est}	=	Forward yield estimated from the curve
σ_r	=	Yield volatility
p	=	Value of option, expressed in yield
BPV	=	Basis point value of underlying bond forward

Formulas

The strike yield, the estimated yield given by the curve, the yield volatility and the time to expiry are entered into the Black 76 option pricing formula. If it is call option, it is entered as a put, and vice versa. This reflects the inverse relation between increases in price and yield. The result from Black 76 is the price of the option expressed in yield. In order to convert this premium to a cash measure, the BPV of the underlying bond forward is used.

$$p = \mathrm{Black76}(r_S, r_{est}, \sigma_r, T) \tag{29}$$

$$NPV = BPV * p * Q * N \tag{30}$$

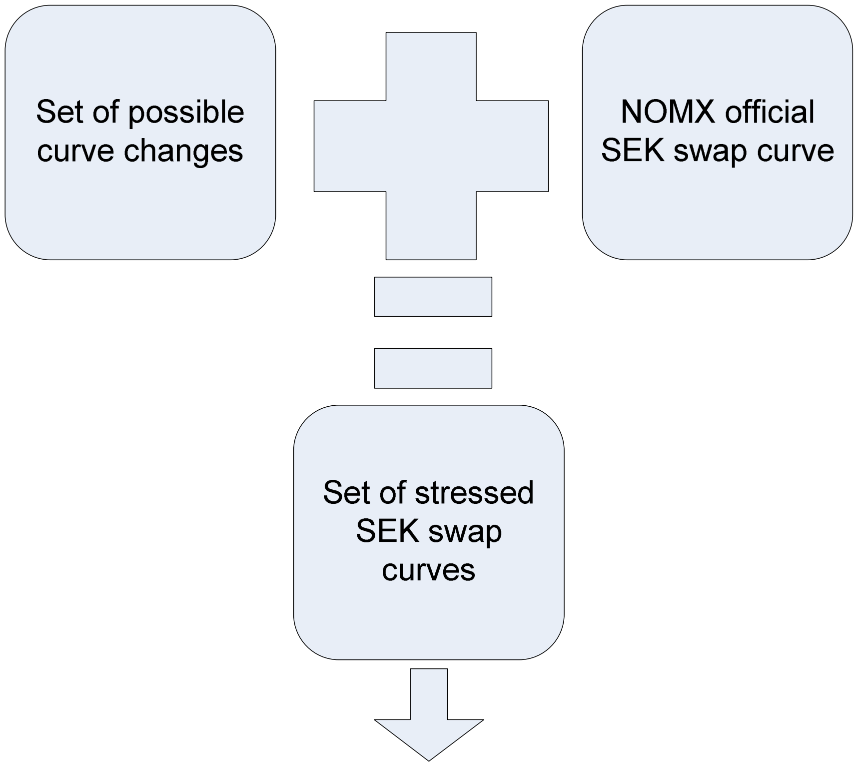
MARGIN CALCULATIONS

This section describes the margin calculations. The section starts with explaining how each individual yield curve will be stressed, and correlation of different yield curves is handled later on in the section.

NAKED MARGIN

Once all OTC positions have been broken up into their future cash flows, then the cash flow tables represent the total risk inherited from the positions in the account. The account's market value is obtained if these cash flows are discounted with the official yield curves i.e. the market value is the position's NPV. However, if the shape of the yield curves changes the net present value of the cash flow tables will also change. NOMX will simulate a number of different stressed yield curves and recalculate the net present value of the cash flow tables using all these curves.

Figure: Schematic picture of the NPV calculations for SEK interest rate swaps.



Value date	SEK (floating)	SEK (fixed)
2010-02-02		$-1 \cdot 5 \cdot 1\,000\,000 \cdot 0{,}3\% \cdot \frac{90}{360}$
2010-05-02	$-1 \cdot 5 \cdot 1\,000\,000 \cdot r_{1,2} \cdot \frac{90}{360}$	
2010-08-02	$-1 \cdot 5 \cdot 1\,000\,000 \cdot r_{2,3} \cdot \frac{90}{360}$	
2010-11-02	$-1 \cdot 5 \cdot 1\,000\,000 \cdot r_{3,4} \cdot \frac{90}{360}$	$1 \cdot 5 \cdot 1\,000\,000 \cdot 1{,}7\% \cdot \frac{360}{360}$
NPV stressed	-170 000	160 000

Obtaining the set of stressed curves

As describes in the "Yield curves" section of this document, NOMX will simulate different curve changes using the curve's principal components (PC).

A risk parameter will be defined per PC and the official spot curve will be stressed ± its PC times that PC's risk parameter. This process is described in more detail in the "Yield curves" section in the beginning of the document and in the margin calculation examples in the end of the document.

An updated version of the risk parameters can be found on: http://nordic.nasdaqomxtrader.com/.

Performing NPV calculations

NOMX will calculate a net present value for each simulated spot curve. This involves the following steps.

- Update the cash flow table's exposed spot curve.
    - Update the corresponding forward-forward curve.
    - Update all floating cash flows in the cash flow table.
- Calculate the net present value of all floating and fixed cash flows in the cash flow table using the recently updated spot curve

Correlation of different yield curves

Yield curves in the same currency but with different credit risks can show a historical relationship. A currency's treasury curve may be seen as the base curve, and the other curves in the same currency can be obtained by applying a credit spread to the treasury curve. NOMX applies the 3D window method in order to account for correlation of different yield curves in the same currency.

The 3D window method might be difficult to digest for someone that is not used to NOMX margin methodology. It is therefore recommended that Appendix III, that describes the 1D window method, is read before this section.

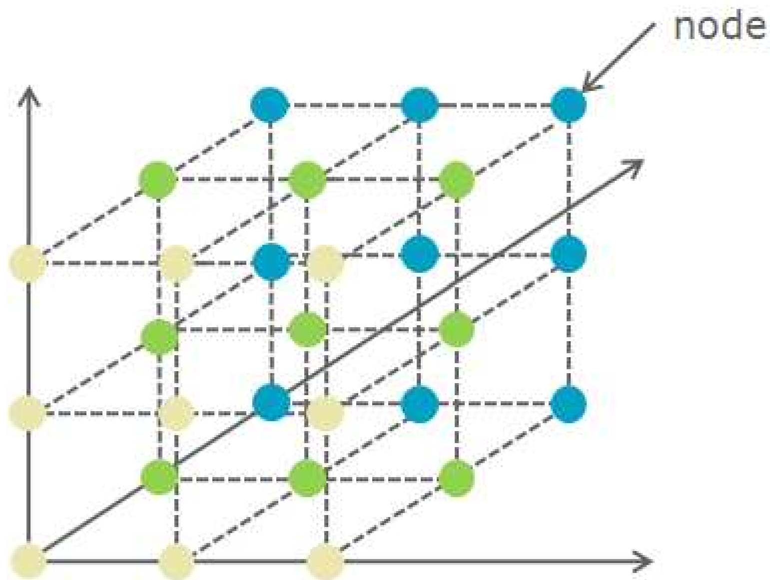
Sample space: Set of stressed curves

NOMX simulates curve changes using the curve's first three principal components. The stressed curves therefore live in a three dimensional sample space$[PC1, PC2, PC3]$.

All principal components will be stressed ± that PC's risk parameter. This implies that all possible curve changes are inside a rectangular prism. This rectangular prism is called the vector cube.

NOMX divides the scanning range intervals $[-PC_i \cdot PC_i's\ risk\ parameter, PC_i \cdot PC_i's\ risk\ parameter]$ into a number of nodes, and the amount of PC_i used in the curve stressing will be evenly distributed over these nodes. Suppose, for example, that the scanning range intervals of the three principal components are divided into 31, 5 and 3 nodes respectively. This would imply that there will be 31 · 5 · 3 = 465 nodes inside the vector cube, and each of these nodes would represent a stressed spot curve.

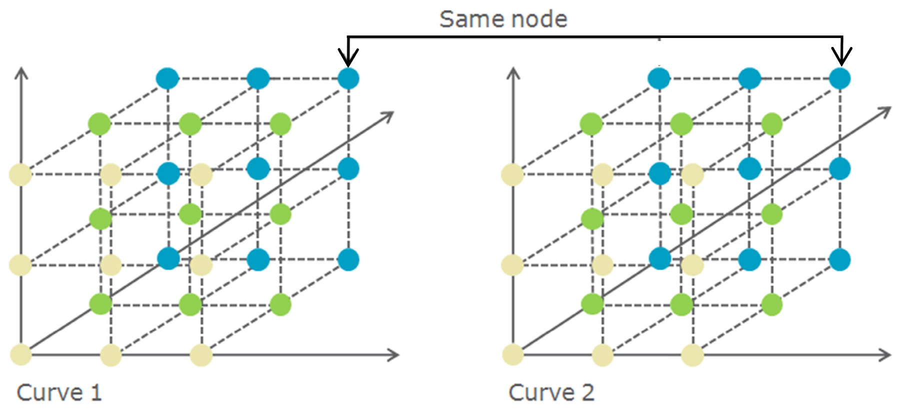
Figure: All stressed curves are inside a vector cube.



CORRELATION MEASURED PER PRINCIPAL COMPONENTS

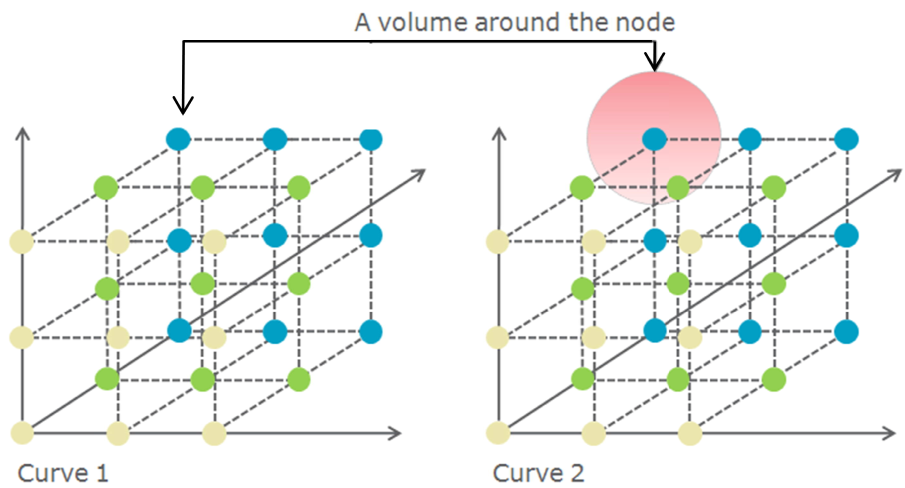
Two yield curves that are 100% correlated cannot deviate from each other. This implies that their stressing would have to be performed in the same nodes.

Figure: Example on two perfect correlated yield curves.



However, two curves that are not 100% correlated may deviate from each other. When the first curve is stressed in one node, then the other curve may be within one of the neighboring nodes. A volume determines the number of nodes that the two curves may deviate from each other, and the size of this volume is determined by the correlation of the two curves. NOMX will determine this size by investigating the yield curves historical correlation in each respective principal component.

Figure: Example of two correlated curves.



PC1

The first principal component is a parallel shift of the entire curve. Suppose there are two curves in the same currency but with different credit rating, for example a treasury curve and a mortgage curve. Further suppose that PC1's risk parameter is 30 basis points for the treasury curve and 33 basis points for the mortgage curve. It would be extremely unlikely that the treasury curve experiences an upward parallel shift of 30 basis points at the same time as the mortgage curve experiences a downward parallel shift of 33 basis points.

NOMX defines a window size for PC1. The window size is given as the amount of nodes that two curves in the same window class may deviate in their PC1 stressing. Suppose for example that the treasury and mortgage curves in the above example are put in the same window class and that their PC1 window size is set to 3. This implies that they may maximum deviate 3 nodes from each other in their PC1 stressing. If the treasury curve were to experience an upward parallel shift of 30 basis points (100% of its risk parameter), then that would imply that the mortgage curve can at minimum experience an upward parallel shift of 29 basis points (3 nodes away from the top of its scanning range interval or 87% of its risk parameter).

Figure: A window size of 3 nodes applied at different nodes.

Treasury		Mortgage		Combined		
Node	Change	Node	Change	Node	Allowed changes (Treasury)	Allowed changes (Mortgage)
1	30	1	33	1	28, 30	31, 33
2	28	2	31	2	26, 28, 30	29, 31, 33
3	26	3	29	3	24, 26, 28	26, 29, 31
4	24	4	26	4	22, 24, 26	24, 26, 29
5	22	5	24	5	20, 22, 24	22, 24, 26
6	20	6	22	6	18, 20, 22	20, 22, 24
7	18	7	20	7	16, 18, 20	18, 20, 22
8	16	8	18	8	14, 16, 18	15, 18, 20
9	14	9	15	9	12, 14, 16	13, 15, 18
10	12	10	13	10	10, 12, 14	11, 13, 15
11	10	11	11	11	8, 10, 12	9, 11, 13
12	8	12	9	12	6, 8, 10	7, 9, 11
13	6	13	7	13	4, 6, 8	4, 7, 9
14	4	14	4	14	2, 4, 6	2, 4, 7
15	2	15	2	15	0, 2, 4	0, 2, 4
16	0	16	0	16	-2, 0, 2	-2, 0, 2
17	-2	17	-2	17	-4, -2, 0	-4, -2, 0
18	-4	18	-4	18	-6, -4, -2	-7, -4, -2
19	-6	19	-7	19	-8, -6, -4	-9, -7, -4
20	-8	20	-9	20	-10, -8, -6	-11, -9, -7
21	-10	21	-11	21	-12, -10, -8	-13, -11, -9
22	-12	22	-13	22	-14, -12, -10	-15, -13, -11
23	-14	23	-15	23	-16, -14, -12	-18, -15, -13
24	-16	24	-18	24	-18, -16, -14	-20, -18, -15
25	-18	25	-20	25	-20, -18, -16	-22, -20, -18
26	-20	26	-22	26	-22, -20, -18	-24, -22, -20
27	-22	27	-24	27	-24, -22, -20	-26, -24, -22
28	-24	28	-26	28	-26, -24, -22	-29, -26, -24
29	-26	29	-29	29	-28, -26, -24	-31, -29, -26
30	-28	30	-31	30	-30, -28, -26	-33,- 31, -30
31	-30	31	-33	31	-30, -28	-33, -31

- A window of 3 nodes applied at node 1 implies that if the treasury curve experiences an upward shift of 28 or 30 basis points, then the mortgage curve may experience an upward shift of 31 or 33 basis points.
- A window of 3 nodes applied at node 10 implies that if the treasury curve experiences an upward shift of 10, 12 or 14 basis points, then the mortgage curve may experience an upward shift of 11, 13 or 15 basis points.
- A window of 3 nodes applied at node 23 implies that if the treasury curve experiences a downward shift of 12, 14 or 16 basis points, then the mortgage curve may experience a downward shift of 13, 15 or 18 basis points.

PC2

The second principal component is a change in the curve's slope. NOMX will also define a window size for this principal component. This window size determines the maximum amount of nodes that two curves in the same window class may deviate from each other in terms of their PC2 stressing.

PC3

The third principal component is a change in the curve's curvature. NOMX will also define a window size for this principal component. This window size determines the maximum amount of nodes that two curves in the same window class may deviate from each other in terms of their PC3 stressing.

Window cubes

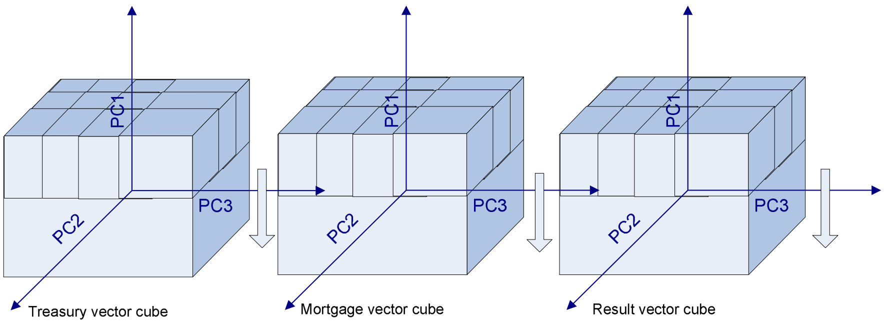
The window sizes for each principal component constitute a rectangular prism (the window cube) in the $[PC1, PC2, PC3]$ space. This prism determines the number of nodes that the curves in the same window class may deviate from each other.

3D window method

The 3D window method starts by listing all vector cubes in the same window class next to each other.

- A result vector cube is created and placed next to the other vector cubes.
- A window cube is placed in every top node of the vector cubes.
  - The result vector's value at node i is the sum of each vector cube's lowest net present value from the nodes inside the window cube that is placed at node i.
- The window cubes will slide down all nodes in the vector cubes and the value in the result vector cube will always be the sum of the lowest net present values from the nodes inside the window cubes.

Figure: 3D window method applied on the treasury and mortgage vector cubes.

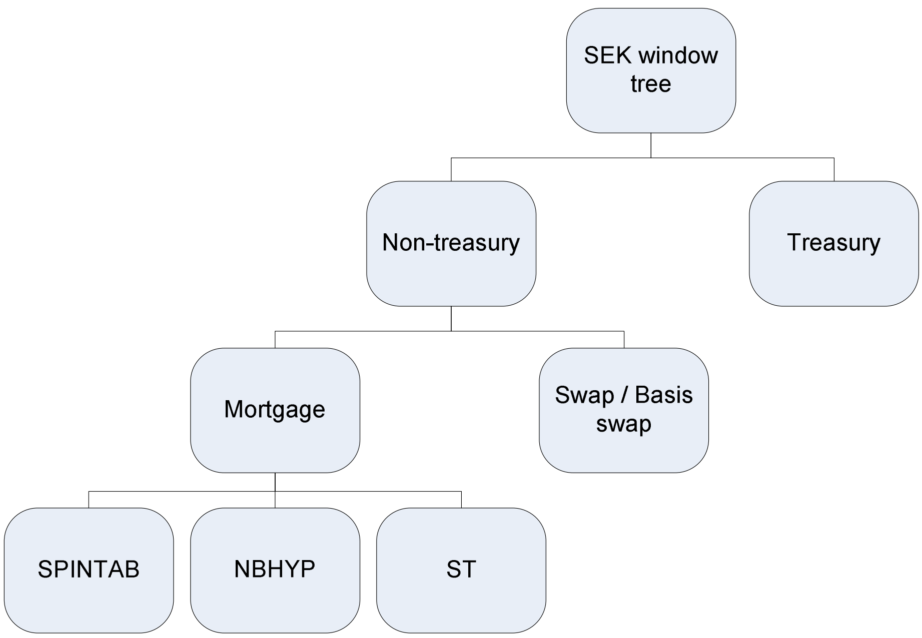


Window trees

The window tree is built up of several layers of window classes and the curves with the closest correlation are placed in the same window class in the bottom of the tree.

The window method is a recursive method; it is first applied to the window classes in the bottom of the window tree. It is here applied on the vector cubes of the cash flow tables within the same window class. During this process a new vector cube, the result vector cube, is created according to the procedures described above. The result vector cube is then combined with result vector cubes from the other window classes in the tree and, as a result, a new result vector cube is created. This procedure is repeated until the top of the window tree has been reached.

Figure: example of a possible SEK window tree



Margin calculation examples

This section presents a few examples on margin calculations.

Example 1

REPO transaction with two open legs

Positions

Considerer a one week REPO in RGKB1045.

Standard	=	Buy and sell back.
t	=	2009-11-02.
t_s	=	2009-11-04.
t_e	=	2009-11-11.
t_m	=	2011-03-15.
t_c	=	2009-03-15.
Q	=	1 000.
N	=	SEK 1 000 000.
C	=	5,25.
Side	=	1.
CP	=	105,89.
r_{repo}	=	0,35%.
C_i	=	

Payment	52 500	1 052 500
Date	2010-03-15	2011-03-15

Cash flow tables

Start consideration

Equation (4) is used to calculate the start consideration. It is 229 days between 2009-03-15 and 2009-11-04 in a 30E convention.

$$X_s = \left(105{,}89 + 5{,}25 \cdot \frac{229}{360}\right) \cdot \frac{1\,000\,000}{100} \cdot 1000 = SEK\ 1\,092\,295\,833$$

End consideration

Equation (6) is used to calculate the end consideration.

$$X_e = 1\,092\,295\,833 \cdot \left(1 + 0{,}35\% \cdot \frac{7}{360}\right) = SEK\ 1\,092\,370\,170$$

This results in the following two cash flow tables.

Start and end consideration cash flow table (swap curve)

Equations (8) – (9) are used to insert the start and end considerations into the start and end consideration cash flow table.

Value date	Time to maturity	SEK
2009-11-04	0,0056	1 092 295 833
2009-11-11	0,025	-1 092 370 170

Treasury cash flow table

Before the start date of the REPO, the underlying bonds have not been exchanged, and since the underlying bonds do not pay any coupons in the interval $[t_s+5,\ t_e+5]$ the cash flows from Equation (11) and Equation (12) will cancel each other out. This implies that the treasury cash flow table will be empty until after the start date of the REPO.

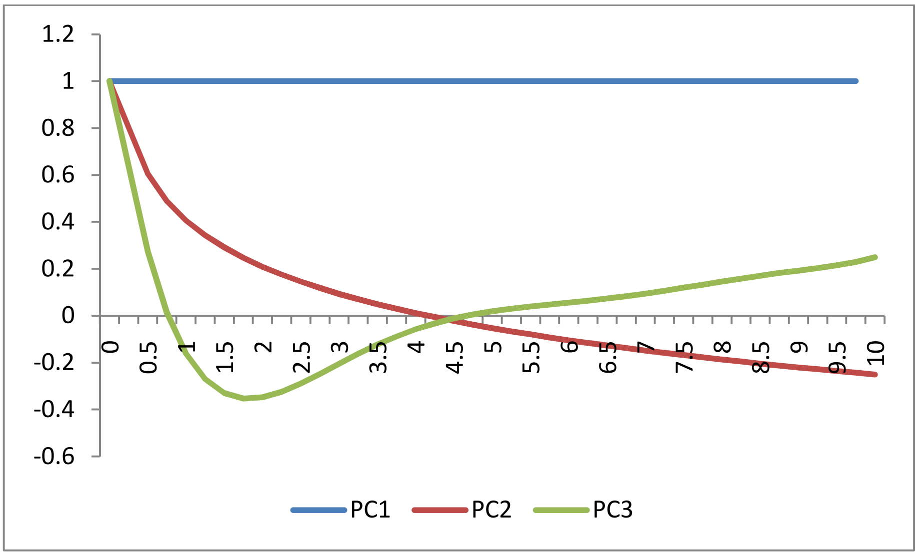
Curve stressing

This position is exposed to a shift in the SEK Treasury spot curve and it is this curve that will be stressed in the margin calculation.

Risk parameters

The shape of the SEK Treasury curve's principal components is shown in the figure below.

Figure: Shape of the SEK Treasury curve's principal components.



The tables below list the stress levels together with the first points of the principal components for the SEK Treasury curve.

Stress levels

Curve	PC1	PC2	PC3
Treasury	22 basis points	8 basis points	5 basis points

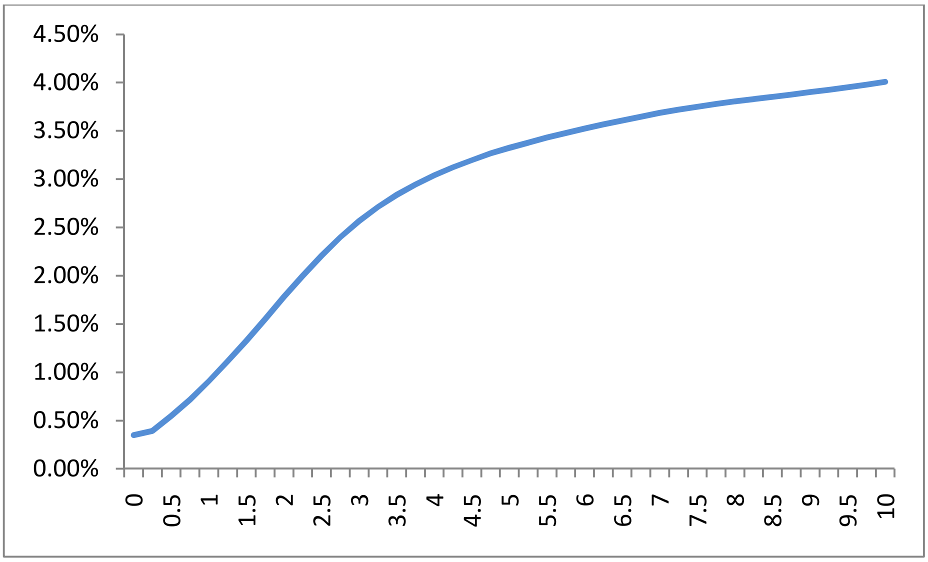
Principal components

Time to maturity	PC1	PC2	PC3
0	1	1	1
0,25	1	0,8	0,64

Official curves

NOMX will, on each trading day, bootstrap official yield curves that will be used to price all cleared instruments. It is the official yield curves that will be stressed in the margin calculations. In this example it is assumed that the official SEK Treasury curve looks as in the figure below.

Figure: Treasury curve



The table below lists the official Treasury spot rates for the time to maturities that are relevant to the cash flows in the start and end consideration cash flow table.

Time to maturity	Spot rate
0,0056	0,351%
0,025	0,354%

Stressed curves

The worst outcome for the position is that the two day SEK Treasury spot rate goes up while the one week SEK Treasury spot rate goes down. This is, however, not a realistic scenario. NOMX will simulate stressed curves with the three principal components and the margin requirement will be based on the worst of these stressed curves.

A cash flow that is due in a long time is more exposed to a shift in the yield curve compared to a cash flow that is due soon. In this example there are only two cash flows and the largest cash flow is the one that has longest time to maturity. This is a negative cash flow (SEK -1 092 370 170) and the worst outcome is therefore that the SEK Treasury curve drops. The worst outcome will be the scenario where all three principal components are stressed downwards.

Figure: All three principal components will be stressed downwards in the worst scenario.

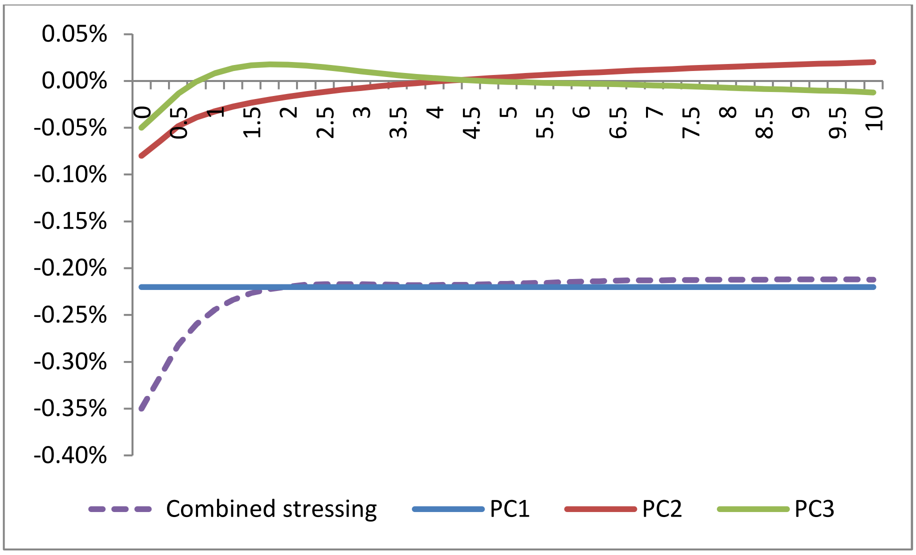
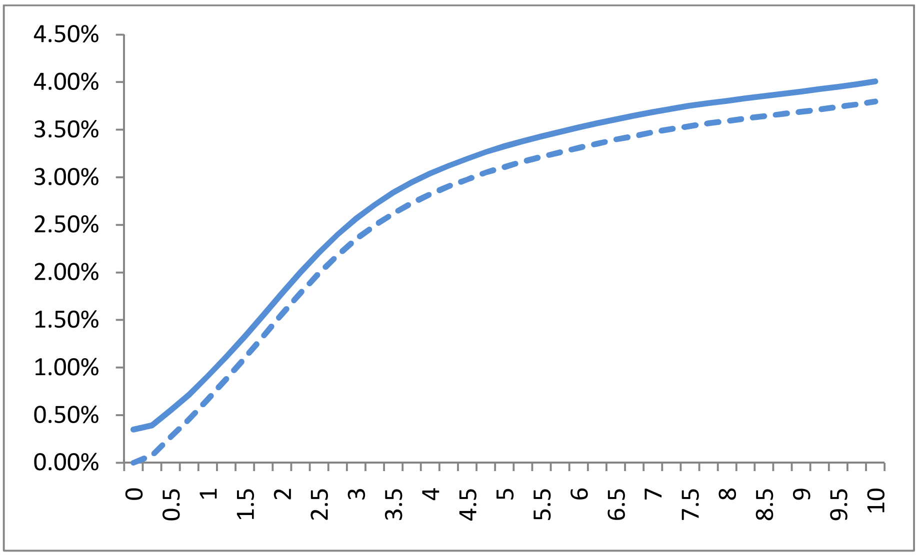


Figure: Official SEK Treasury curve and stressed SEK Treasury curve



NOMX defines the principal components in a predefined number of nodes. The distance between each node is in this example 0,25 years. It is, however, 0,0056 years to the start date of the REPO and 0,025 years to the end date of the REPO. A linear interpolation will be used in order to determine the stress levels for these maturities. This can be seen in the table below.

Time to maturity	PC1	PC2	PC3
0	1	1	1
0,0056	1	$1+\frac{0,8-1}{0,25-0}\cdot(0,0056-0) = 0,99552$	$1+\frac{0,64-1}{0,25-0}\cdot(0,0056-0) = 0,991936$
0,025	1	$1+\frac{0,8-1}{0,25-0}\cdot(0,025-0)=0,98$	$1+\frac{0,64-1}{0,25-0}\cdot(0,025-0)=0,964$
0,25	1	0,8	0,64

The table below shows the stressed Treasury spot rates when the three principal components are stressed downwards.

Time to maturity	Spot rate	Stressed spot rate
0,0056	0,351%	$0{,}351\% - 0{,}22\% \cdot 1 - 0{,}08\% \cdot 0{,}99552 - 0{,}05\% \cdot 0{,}991936 = 0{,}001762\%$
0,025	0,354%	$0{,}354\% - 0{,}22\% \cdot 1 - 0{,}08\% \cdot 0{,}98 - 0{,}05\% \cdot 0{,}964 = 0{,}0074\%$

NET PRESENT VALUE

The margin requirement is obtained by calculating the net present value of the cash flows in all cash flow tables.

In this example all cash flows are in SEK and are exposed to the Treasury curve. If the net present value is calculated with the official SEK Treasury curve, then the REPO position's market value is obtained. If, on the other hand, the net present value is calculated with the stressed SEK Treasury curve, then the REPO position's margin requirement is obtained.

Value date	Time to maturity	SEK
2009-11-04	0,0056	1 092 295 833
2009-11-11	0,025	-1 092 370 170
NPV		$\frac{1\ 092\ 295\ 833}{(1+0{,}351\%)^{0{,}0056}} - \frac{1\ 092\ 370\ 170}{(1+0{,}354\%)^{0{,}025}} = 730$
NPV stressed		$\frac{1\ 092\ 295\ 833}{(1+0{,}001762\%)^{0{,}0056}} - \frac{1\ 092\ 370\ 170}{(1+0{,}0074\%)^{0{,}025}} = -72\ 424$

Market value = SEK 730

It can be noted that NOMX gives the REPO position a market value that is not zero even though the position was just entered. This is because the NPV are calculated from a yield curve (a constructed average) and the repo rates are actual agreed transfer rates between parties.

Margin requirement = SEK -72 424

Example 2

REPO transaction with one open leg

Positions

This example contains the same position as in Example 1, i.e. a one week REPO in RGKB1045. However, this example describes the margin calculations performed at 2009-11-04 when the first leg has settled.

Start and end consideration cash flow table

The first leg has settled so it is only the end consideration that is left in the start and end consideration cash flow table.

Value date	Time to maturity	SEK
2009-11-11	0,1944	-1 092 370 170

Treasury cash flow table

Equation (12) is used to insert the cash flows from the underlying bond, which is to be exchanged on the end date, into the treasury cash flow table.

Value date	Time to maturity	SEK
2010-03-15	0,3639	$1\,000 \cdot 52\,500 = 52\,500\,000$
2011-03-15	1,3639	$1\,000 \cdot 1\,052\,500 = 1\,052\,500\,000$

Curve stressing

This position is exposed to shifts in the SEK Treasury spot curve

Risk parameters

The tables below list the stress levels together with the first points of the principal components.

Stress levels

Curve	PC1	PC2	PC3
Treasury	22 basis points	8 basis points	5 basis points

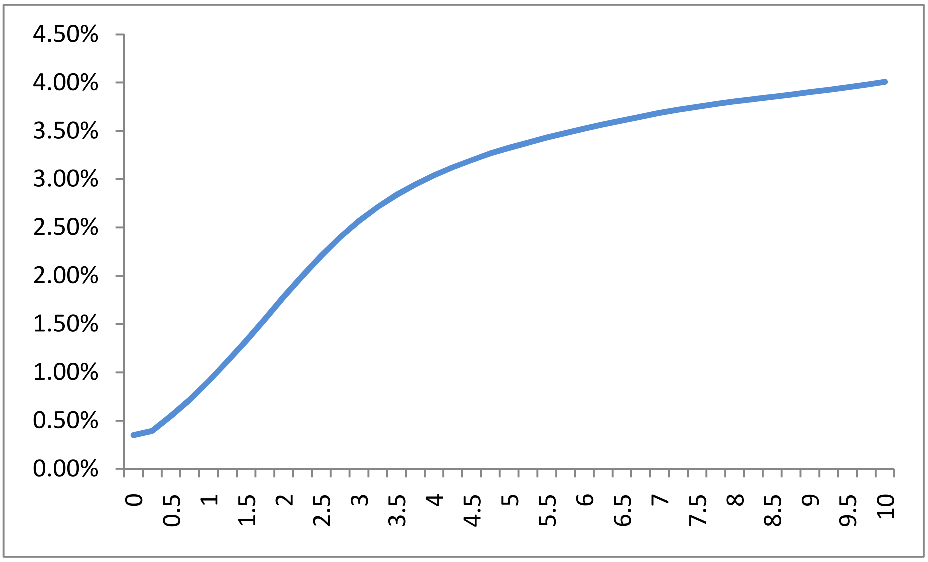
Principal components

Time to maturity	PC1	PC2	PC3
0	1	1	1
0,25	1	0,8	0,64
0,5	1	0,6	0,27
0,75	1	0,49	0,02
1	1	0,41	-0,16
1,25	1	0,34	-0,27
1,5	1	0,29	-0,33

Official curves

NOMX will, on each trading day, bootstrap official yield curves that will be used to price all cleared instruments. It is the official yield curves that will be stressed in the margin calculations. In this example it is assumed that the official SEK treasury curve look as in the figure below.

Figure: Treasury curve



The tables below list the treasury spot rates for the time to maturities that are relevant to the cash flows in the start and end consideration cash flow table and in the treasury cash flow table.

SEK TREASURY

Time to maturity	Spot rate
0,01944	0,352%
0,3639	0,40%
1,3639	1,15%

Stressed curves

The first cash flow is a negative one and thus the worst scenario for that cash flow will be that all short SEK treasury spot rates goes down. However, the position's cash flows that are most distance are the ones that are derived from the underlying bond. These are all positive cash flows and hence these positions are mainly exposed to an upward shift in the SEK treasury curve; especially that the interest rate with maturity 1,3639 years goes up. If one considers all cash flows, the worst outcome will be the scenario where the first two principal components are stressed upwards and the third principal component is stressed downwards.

Figure: The worst scenario is when the SEK treasury curve is stressed upward.

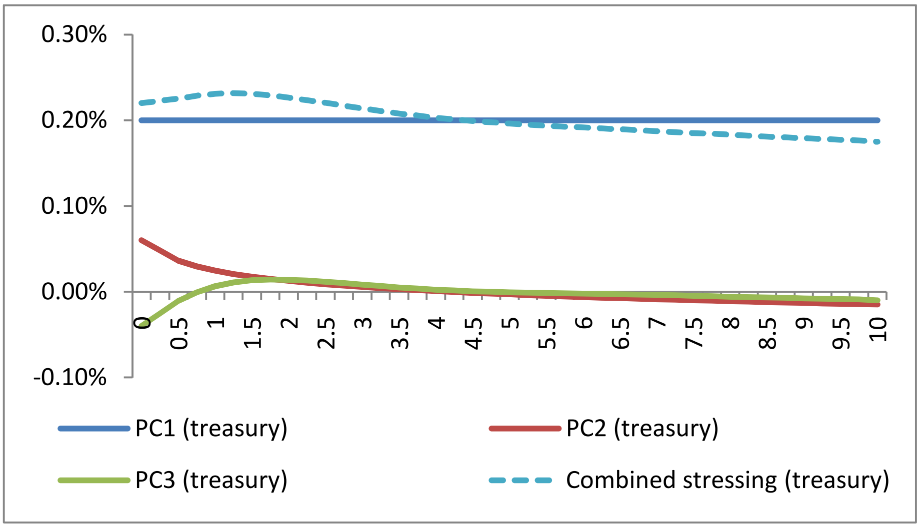
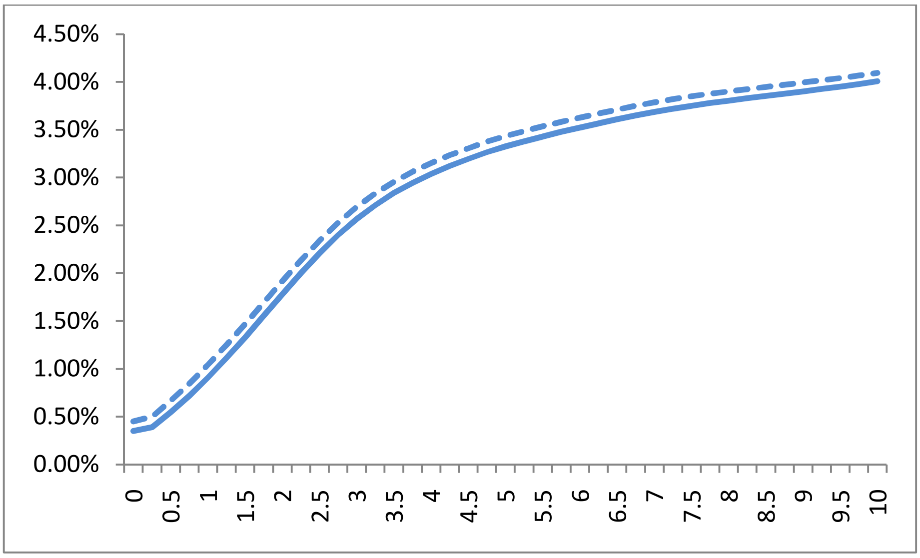


Figure: Official curve and stressed curve.



NOMX defines the principal components in a predefined number of nodes. The distance between each node is in this example 0,25 years. A linear interpolation will be used in order to determine the stress levels for the maturities that lay in between these nodes. This can be seen in the table below.

Time to maturity	PC1	PC2	PC3
0	1	1	1
0,01944	1	$1+\frac{0,8-1}{0,25-0}\cdot(0,001944-0)$ $=0,9844$	$1+\frac{0,64-1}{0,25-0}\cdot(0,01944-0)=0,9720$
0,25	1	0,8	0,64
0,3639	1	$0,8+\frac{0,6-0,8}{0,5-0,25}\cdot(0,3639-0,25)=$ $=0,7089$	$0,64+\frac{0,27-0,64}{0,5-0,25}\cdot(0,3639-0,25)=$ $=0,4714$
0,5	1	0,6	0,27
0,75	1	0,49	0,02
1	1	0,41	-0,16
1,25	1	0,34	-0,27
1,3639	1	$0,34+\frac{0,29-0,34}{1,5-1,25}\cdot(1,3589-1,25)$ $=0,3172$	$-0,27+\frac{-0,33+0,27}{1,5-1,25}$ $\cdot(1,3639-1,25)$ $=-0,2973$
1,5	1	0,29	-0,33

SEK TREASURY

The table below shows the stressed treasury spot rates when the first two principal components are stressed upwards and the third principal component is stressed downwards.

Time to maturity	Spot rate	Stressed spot rate
0,01944	0,352%	$0,352\%+0,22\%\cdot1+0,08\%\cdot0,9844-0,05\%\cdot0,9720$ $=0,6022\%$
0,3639	0,40%	$0,40\%+0,22\%\cdot1+0,08\%\cdot0,7089-0,05\%\cdot0,4714$ $=0,6531\%$
1,3639	1,15%	$1,15\%+0,22\%\cdot1+0,08\%\cdot0,3172+0,05\%\cdot0,2973$ $=1,4102\%$

Net present value

The margin requirement is obtained by calculating the net present value of the cash flows in the cash flow table.

If the net present value is calculated with the official SEK treasury curve, then the position's market value is obtained. If, on the other hand, the net present value is calculated with the stressed treasury curve, then the position's margin requirement is obtained.

Start and end consideration cash flow table

Value date	Time to maturity	SEK
2009-11-11	0,01944	-1 092 370 170
NPV (X_e)		$-\frac{1\ 092\ 370\ 170}{(1+0{,}352\%)^{0{,}01944}} = -1\ 092\ 296\ 554$
NPV stressed ($\mathbf{X_e}$)		$-\frac{1\ 092\ 370\ 170}{(1+0{,}6022\%)^{0{,}01944}} = -1\ 092\ 242\ 680$

Cash flow table derived from the underlying bond

Value date	Time to maturity	SEK
2010-03-15	0,3639	52 500 000
2011-03-15	1,3639	1 052 500 000
NPV		$\frac{52\ 500\ 000}{(1+0{,}40\%)^{0{,}3639}} + \frac{1\ 052\ 500\ 000}{(1+1{,}15\%)^{1{,}3639}} = 1\ 088\ 637\ 014$
NPV stressed		$\frac{52\ 500\ 000}{(1+0{,}6531\%)^{0{,}3639}} + \frac{1\ 052\ 500\ 000}{(1+1{,}4102\%)^{1{,}3639}} = 1\ 084\ 964\ 453$

Market value = SEK 1 088 637 014 – SEK 1 092 296 554 = **SEK -3 659 540**

Margin requirement = SEK 1 084 964 453 – SEK 1 092 242 680 = **SEK -7 278 227**

Example 3

Spread position in a REPO transaction

Positions

Considerer a one week REPO in RGKB1049 versus a one week reversed REPO in RGKB1050. These positions are traded on 2009-11-02, but the margin calculation presented here is performed on 2009-11-04 after their first legs have settled.

One week REPO in RGKB1049

Standard	=	Buy and sell back.
t	=	2009-11-04.
t_s	=	2009-11-04.
t_e	=	2009-11-11.
t_m	=	2015-08-12.
t_c	=	2009-08-12.
Q	=	1 000.
N	=	SEK 1 000 000.
C	=	4,5.
Side	=	1.
CP	=	108,94
r_{repo}	=	0,35%.
C_i	=	see table below

Payment	45 000	...	45 000	1 045 000
Date	2010-08-12	...	2014-08-12	2015-08-12

One week reversed REPO in RGKB1050

Standard	=	Buy and sell back.
t	=	2009-11-04.
t_s	=	2009-11-04.
t_e	=	2009-11-11.
t_m	=	2016-07-12.
t_c	=	2009-07-12.
Q	=	1 000.
N	=	SEK 1 000 000.
C	=	3.
Side	=	-1.
CP	=	98,50.
r_{repo}	=	0,35%.
C_i	=	see table below

Payment	30 000	...	30 000	1 030 000
Date	2010-07-12	...	2015-07-12	2016-07-12

Cash flow tables

Start consideration

RGKB1049

Equation (4) is used to calculate the start consideration. It is 82 days between 2009-08-12 and 2009-11-04 in a 30E convention.

$$X_s = \left(108{,}94 + 4{,}5 \cdot \frac{82}{360}\right) \cdot \frac{1\,000\,000}{100} \cdot 1000 = SEK\ 1\,099\,650\,000$$

RGKB1050

Equation (4) is used to calculate the start consideration. It is 112 days between 2009-07-12 and 2009-11-04 in a 30E convention.

$$X_s = \left(98{,}50 + 3 \cdot \frac{112}{360}\right) \cdot \frac{1\,000\,000}{100} \cdot 1000 = SEK\ 994\,333\,333$$

END CONSIDERATION

RGKB1049

Equation (6) is used to calculate the end consideration.

$$X_e = 1\,099\,650\,000 \cdot \left(1 + 0{,}35\% \cdot \frac{7}{360}\right) = SEK\ 1\,099\,724\,837$$

RGKB1050

Equation (6) is used to calculate the end consideration.

$$X_e = 994\,333\,333 \cdot \left(1 + 0{,}35\% \cdot \frac{7}{360}\right) = SEK\ 994\,401\,003$$

This results in the following two cash flow tables.

START AND END CONSIDERATION CASH FLOW TABLE

The first leg has settled so it is only the end considerations that remain in the start and end consideration cash flow table. These have been entered using Equation (9).

Value date	Time to maturity	SEK
2009-11-11	0,01944	-1 099 724 837 + 994 401 003 = -105 323 834

CASH FLOW TABLE DERIVED FROM THE UNDERLYING BONDS

Equation (12) is used to insert the cash flows from the underlying bonds, which are to be exchanged on the end date, into the treasury cash flow table.

Value date	Time to maturity	SEK
2010-07-12	0,6889	$-1\,000 \cdot 30\,000 = -30\,000\,000$
2010-08-12	0,7722	$1\,000 \cdot 45\,000 = 45\,000\,000$
2011-07-12	1,6889	$-1\,000 \cdot 30\,000 = -30\,000\,000$
2011-08-12	1,7722	$1\,000 \cdot 45\,000 = 45\,000\,000$
2012-07-12	2,6889	$-1\,000 \cdot 30\,000 = -30\,000\,000$
2012-08-12	2,7722	$1\,000 \cdot 45\,000 = 45\,000\,000$
2013-07-12	3,6889	$-1\,000 \cdot 30\,000 = -30\,000\,000$
2013-08-12	3,7722	$1\,000 \cdot 45\,000 = 45\,000\,000$
2014-07-12	4,6889	$-1\,000 \cdot 30\,000 = -30\,000\,000$
2014-08-12	4,7722	$1\,000 \cdot 45\,000 = 45\,000\,000$
2015-07-12	5,6889	$-1\,000 \cdot 30\,000 = -30\,000\,000$
2015-08-12	5,7722	$1\,000 \cdot 1\,045\,000 = 1\,045\,000\,000$
2016-07-12	6,6889	$-1\,000 \cdot 1\,030\,000 = -1\,030\,000\,000$

CURVE STRESSING

This combined position is exposed to shifts in the SEK treasury spot curve. The treasury curve will be stressed in the margin calculation.

Risk parameters

The tables below list the stress levels together with the first points on the principal components.

Stress levels

Curve	PC1	PC2	PC3
Treasury	22 basis points	8 basis points	5 basis points

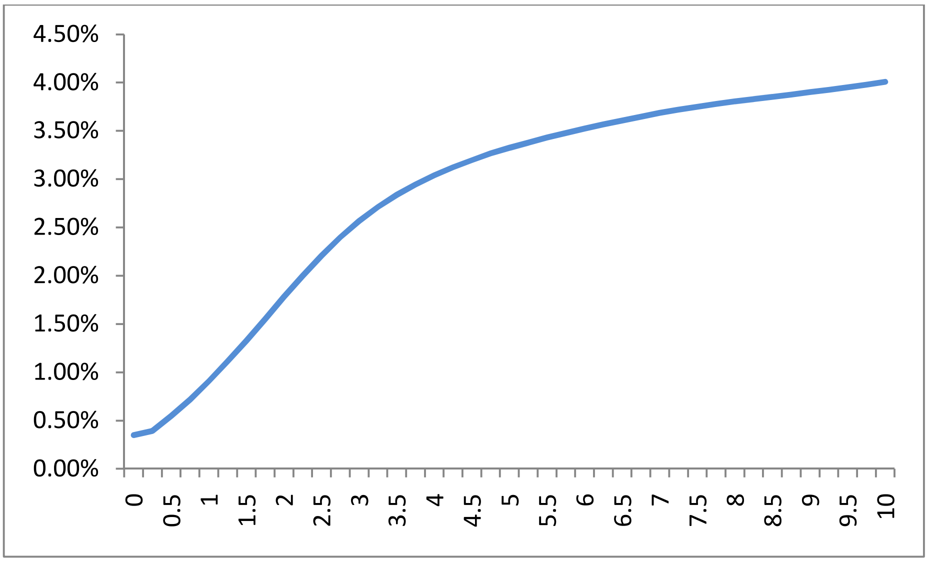
Principal components

Time to maturity	PC1	PC2	PC3
0	1	1	1
0,25	1	0,8	0,64
0,5	1	0,6	0,27
0,75	1	0,49	0,02
1	1	0,41	-0,16
1,25	1	0,34	-0,27
1,5	1	0,29	-0,33
1,75	1	0,25	-0,35
2	1	0,21	-0,35
2,25	1	0,18	-0,32
2,5	1	0,15	-0,29
2,75	1	0,12	-0,25
3	1	0,09	-0,21
3,25	1	0,07	-0,16
3,5	1	0,05	-0,12
3,75	1	0,03	-0,09
4	1	0,01	-0,06
4,25	1	-0,01	-0,03
4,5	1	-0,02	-0,01
4,75	1	-0,04	0,01
5	1	-0,05	0,02
5,25	1	-0,07	0,03
5,5	1	-0,08	0,04
5,75	1	-0,09	0,05
6	1	-0,1	0,06
6,25	1	-0,12	0,06
6,5	1	-0,13	0,07
6,75	1	-0,14	0,08

OFFICIAL CURVES

NOMX will, on each trading day, bootstrap official yield curves that will be used to price all cleared instruments. It is the official yield curves that will be stressed in the margin calculations. In this example it is assumed that the official SEK treasury curve look as in the figure below.

Figure: Official SEK treasury curve



The tables below list the official treasury spot rates for the time to maturities that are relevant to the cash flows in the start and end consideration cash flow table and in the treasury cash flow table.

SEK TREASURY

Time to maturity	Spot rate
0,01944	0,352%
0,6889	0,62%
0,7722	0,89%
1,6889	1,44%
1,7722	1,87%
2,6889	2,29%
2,7722	2,57%
3,6889	2,86%
3,7722	3,03%
4,6889	3,19%
4,7722	3,30%
5,6889	3,41%
5,7722	3,49%
6,6889	3,58%

STRESSED CURVES

This combined position is mainly exposed to a downward shift in the SEK treasury curve. The worst outcome for the SEK treasury curve will therefore be a downward stressing combined with a change in slope. This is the scenario where the first and the third principal components are stressed downwards and the second principal component is stressed upwards.

Figure: The worst scenario is when the SEK treasury curve is stressed downwards.

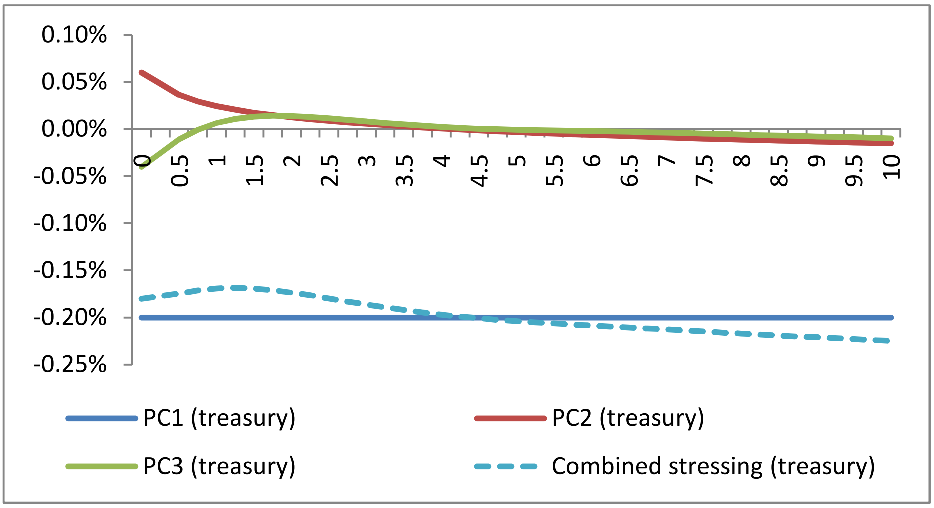
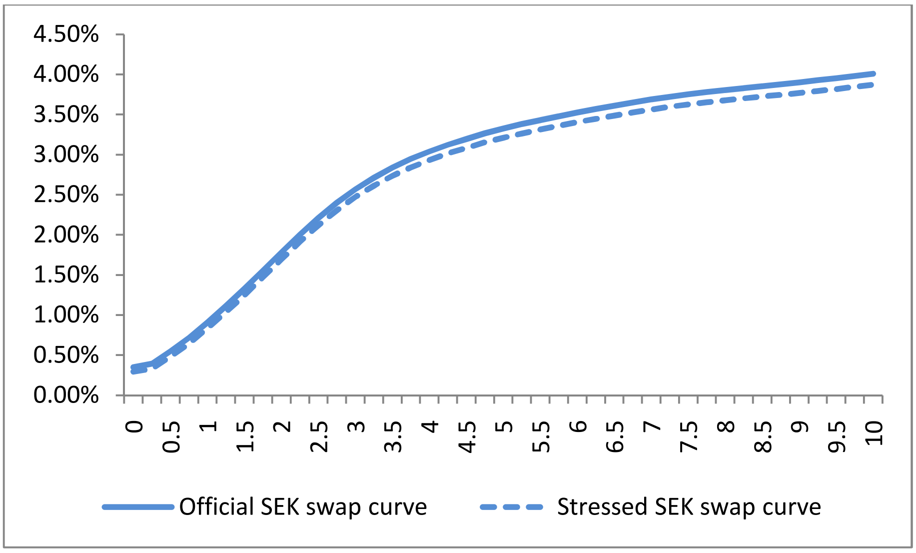


Figure: Official curves and stressed curves.



NOMX defines the principal components in a predefined number of nodes. The distance between each node is in this example 0,25 years. A linear interpolation will be used in order to determine the stress levels for the maturities that lay in between these nodes. This can be seen in the table below.

Time to maturity	PC1	PC2	PC3
0	1	1	1
0,01944	1	$1+\frac{0{,}8-1}{0{,}25-0}\cdot(0{,}01944-0) = 0{,}9844$	$1+\frac{0{,}64-1}{0{,}25-0}\cdot(0{,}01944-0)=0{,}9720$
0,25	1	0,8	0,64
0,5	1	0,6	0,27
0,6889	1	$0{,}6+\frac{0{,}49-0{,}6}{0{,}75-0{,}5}\cdot(0{,}6889-0{,}5) = 0{,}5169$	$0{,}27+\frac{0{,}02-0{,}27}{0{,}75-0{,}5}\cdot(0{,}6889-0{,}5) = 0{,}0811$
0,75	1	0,49	0,02
0,7722	1	$0{,}49+\frac{0{,}41-0{,}49}{1-0{,}75}\cdot(0{,}7722-0{,}75) = 0{,}4829$	$0{,}02+\frac{-0{,}16-0{,}02}{1-0{,}75}\cdot(0{,}7722-0{,}75) = 0{,}0040$
1	1	0,41	-0,16
1,25	1	0,34	-0,27
1,5	1	0,29	-0,33
1,6889	1	$0{,}29+\frac{0{,}25-0{,}29}{1{,}75-1{,}5}\cdot(1{,}6889-1{,}5) = 0{,}2598$	$-0{,}33+\frac{-0{,}35+0{,}33}{1{,}75-1{,}5}\cdot(1{,}6889-1{,}5) = -0{,}3451$
1,75	1	0,25	-0,35
1,7722	1	$0{,}25+\frac{0{,}21-0{,}25}{2-1{,}75}\cdot(1{,}7722-1{,}75) = 0{,}2464$	$-0{,}35+\frac{-0{,}35+0{,}35}{2-1{,}75}\cdot(1{,}7722-1{,}75) = -0{,}35$
2	1	0,21	-0,35
2,25	1	0,18	-0,32
2,5	1	0,15	-0,29
2,6889	1	$0{,}15+\frac{0{,}12-0{,}15}{2{,}75-2{,}5}\cdot(2{,}6889-2{,}5) = 0{,}1273$	$-0{,}29+\frac{-0{,}25+0{,}29}{2{,}75-2{,}5}\cdot(2{,}6889-2{,}5) = -0{,}2598$
2,75	1	0,12	-0,25
2,7722	1	$0{,}12+\frac{0{,}09-0{,}12}{3-2{,}75}\cdot(2{,}7722-2{,}75) = 0{,}1173$	$-0{,}25+\frac{-0{,}21+0{,}25}{3-2{,}75}\cdot(2{,}7722-2{,}75) = -0{,}2464$
3	1	0,09	-0,21
3,25	1	0,07	-0,16
3,5	1	0,05	-0,12
3,6889	1	$0{,}05+\frac{0{,}03-0{,}05}{3{,}75-3{,}5}\cdot(3{,}6889-3{,}5) = 0{,}0349$	$-0{,}12+\frac{-0{,}09+0{,}12}{3{,}75-3{,}5}\cdot(3{,}6889-3{,}5) = -0{,}0973$
3,75	1	0,03	-0,09
3,7722	1	$0{,}03+\frac{0{,}01-0{,}03}{4-3{,}75}\cdot(3{,}7722-3{,}75) = 0{,}0282$	$-0{,}09+\frac{-0{,}06+0{,}09}{4-3{,}75}\cdot(3{,}7722-3{,}75) = -0{,}0873$
4	1	0,01	-0,06
4,25	1	-0,01	-0,03
4,5	1	-0,02	-0,01
4,6889	1	$-0{,}02+\frac{-0{,}04+0{,}02}{4{,}75-4{,}5}\cdot(4{,}6889-4{,}5) = -0{,}0351$	$-0{,}01+\frac{0{,}01+0{,}01}{4{,}75-4{,}5}\cdot(4{,}6889-4{,}5) = 0{,}0051$
4,75	1	-0,04	0,01
4,7722	1	$-0{,}04+\frac{-0{,}05+0{,}04}{5-4{,}75}\cdot(4{,}7722-4{,}75) = -0{,}0409$	$0{,}01+\frac{0{,}02-0{,}01}{5-4{,}75}\cdot(4{,}7722-4{,}75) = 0{,}0109$
5	1	-0,05	0,02
5,25	1	-0,07	0,03
5,5	1	-0,08	0,04

5,6889	1	$-0{,}08+\frac{-0{,}09+0{,}08}{5{,}75-5{,}5}\cdot(5{,}6889-5{,}5)=-0{,}0876$	$0{,}04+\frac{0{,}05-0{,}04}{5{,}75-5{,}5}\cdot(5{,}6889-5{,}5)=0{,}0476$
5,75	1	-0,09	0,05
5,7722	1	$-0{,}09+\frac{-0{,}1+0{,}09}{6-5{,}75}\cdot(5{,}7722-5{,}75)=-0{,}0909$	$0{,}05+\frac{0{,}06-0{,}05}{6-5{,}75}\cdot(5{,}7722-5{,}75)=0{,}0509$
6	1	-0,1	0,06
6,25	1	-0,12	0,06
6,5	1	-0,13	0,07
6,6889	1	$-0{,}13+\frac{-0{,}14+0{,}13}{6{,}75-6{,}5}\cdot(6{,}69-6{,}5)=-0{,}1376$	$0{,}07+\frac{0{,}08-0{,}07}{6{,}75-6{,}5}\cdot(6{,}6889-6{,}5)=0{,}0776$
6,75	1	-0,14	0,08

SEK TREASURY

The table below shows the stressed treasury spot rates when the first and the third principal components are stressed downwards and the second principal component is stressed upwards.

Time to maturity	Spot rate	Spot rate stressed
0,01944	0,352%	$0{,}352\%-0{,}22\%\cdot 1+0{,}08\%\cdot 0{,}9844-0{,}05\%\cdot 0{,}9720=0{,}162\%$
0,6889	0,62%	$0{,}62\%-0{,}22\%\cdot 1+0{,}08\%\cdot 0{,}5169-0{,}05\%\cdot 0{,}0811=0{,}437\%$
0,7722	0,89%	$0{,}89\%-0{,}22\%\cdot 1+0{,}08\%\cdot 0{,}4829-0{,}05\%\cdot 0{,}0040=0{,}708\%$
1,6889	1,44%	$1{,}44\%-0{,}22\%\cdot 1+0{,}08\%\cdot 0{,}2598+0{,}05\%\cdot 0{,}3451=1{,}258\%$
1,7722	1,87%	$1{,}87\%-0{,}22\%\cdot 1+0{,}08\%\cdot 0{,}2464+0{,}05\%\cdot 0{,}35=1{,}687\%$
2,6889	2,29%	$2{,}29\%-0{,}22\%\cdot 1+0{,}08\%\cdot 0{,}1273+0{,}05\%\cdot 0{,}2598=2{,}093\%$
2,7722	2,57%	$2{,}57\%-0{,}22\%\cdot 1+0{,}08\%\cdot 0{,}1173+0{,}05\%\cdot 0{,}2464=2{,}372\%$
3,6889	2,86%	$2{,}86\%-0{,}22\%\cdot 1+0{,}08\%\cdot 0{,}0349+0{,}05\%\cdot 0{,}0973=2{,}648\%$
3,7722	3,03%	$3{,}03\%-0{,}22\%\cdot 1+0{,}08\%\cdot 0{,}0282+0{,}05\%\cdot 0{,}0873=2{,}817\%$
4,6889	3,19%	$3{,}19\%-0{,}22\%\cdot 1-0{,}08\%\cdot 0{,}0351-0{,}05\%\cdot 0{,}0051=2{,}967\%$
4,7722	3,30%	$3{,}30\%-0{,}22\%\cdot 1-0{,}08\%\cdot 0{,}0409-0{,}05\%\cdot 0{,}0109=3{,}076\%$
5,6889	3,41%	$3{,}41\%-0{,}22\%\cdot 1-0{,}08\%\cdot 0{,}0876-0{,}05\%\cdot 0{,}0476=3{,}181\%$

5,7722	3,49%	$3{,}49\% - 0{,}22\% \cdot 1 - 0{,}08\% \cdot 0{,}0909 - 0{,}05\% \cdot 0{,}0509 = 3{,}260\%$
6,6889	3,58%	$3{,}58\% - 0{,}22\% \cdot 1 - 0{,}08\% \cdot 0{,}1376 - 0{,}05\% \cdot 0{,}0776 = 3{,}345\%$

Net present value

The margin requirement is obtained by calculating the net present value of the cash flows in the cash flow table.

If the net present value is calculated with the official SEK treasury curve, then the combined position's market value is obtained. If, on the other hand, the net present value is calculated with the stressed SEK treasury curve, then the combined position's margin requirement is obtained.

Start and end consideration cash flow table

Value date	Time to maturity	SEK
2009-11-11	0,01944	$-105\,323\,834$
NPV		$-\frac{-105\,323\,834}{(1+0{,}352\%)^{0{,}01944}} = -105\,316\,640$
NPV stressed		$-\frac{105\,323\,834}{(1+0{,}162\%)^{0{,}01944}} = -105\,320\,520$

Cash flow table derived from the underlying bonds

Value date	Time to maturity	SEK
2010-07-12	0,6889	$-1\,000 \cdot 30\,000 = -30\,000\,000$
2010-08-12	0,7722	$1\,000 \cdot 45\,000 = 45\,000\,000$
2011-07-12	1,6889	$-1\,000 \cdot 30\,000 = -30\,000\,000$
2011-08-12	1,7722	$1\,000 \cdot 45\,000 = 45\,000\,000$
2012-07-12	2,6889	$-1\,000 \cdot 30\,000 = -30\,000\,000$
2012-08-12	2,7722	$1\,000 \cdot 45\,000 = 45\,000\,000$
2013-07-12	3,6889	$-1\,000 \cdot 30\,000 = -30\,000\,000$
2013-08-12	3,7722	$1\,000 \cdot 45\,000 = 45\,000\,000$
2014-07-12	4,6889	$-1\,000 \cdot 30\,000 = -30\,000\,000$
2014-08-12	4,7722	$1\,000 \cdot 45\,000 = 45\,000\,000$
2015-07-12	5,6889	$-1\,000 \cdot 30\,000 = -30\,000\,000$
2015-08-12	5,7722	$1\,000 \cdot 1\,045\,000 = 1\,045\,000\,000$
2016-07-12	6,6889	$-1\,000 \cdot 1\,030\,000 = -1\,030\,000\,000$
NPV		$\frac{-30\,000\,000}{(1+0{,}62\%)^{0{,}6889}} + \cdots + \frac{-1\,030\,000\,000}{(1+3{,}58\%)^{6{,}6889}} = 86\,807\,192$
NPV stressed		$\frac{-30\,000\,000}{(1-0{,}437\%)^{0{,}6889}} + \cdots + \frac{-1\,030\,000\,000}{(1+3{,}345\%)^{6{,}6889}} = 85\,742\,056$

Market value = SEK 86 807 192 – SEK 105 316 640 = **SEK -18 509 448**

Margin requirement = SEK 85 742 056 – SEK 105 320 520 = **SEK -19 578 464**

Example 5

Interest rate swap

Positions

Consider a bought 2Y plain vanilla SEK fixed for floating interest rate swap. The position is traded on 2009-11-02, but the margin calculation presented here is performed on 2009-11-04. In this example it has, for simplicity, been assumed that all floating rate periods have 90 days and that all fixed rate periods have 360 days.

t_s = 2009-11-04.
t_e = 2011-11-04.
Q = 1.
N = 1 000 000.
Side = 1.
$d_{i,i+1}$ = 90.
r_{fl} = 0,391%.
r_f = 1,773%.
$d_{f,i,i+1}$ = 360.

Cash flow tables

Equation (13) is used to insert the floating cash flows into the swap cash flow table. Equations (15) – (16) are used to insert the fixed cash flows into the swap cash flow table. It should be noted that the value of the floating cash flows will be updated when the swap spot curve changes.

Swap cash flow table

Value date	Time to maturity	SEK (floating)	SEK (fixed)
2010-02-04	0,25		$1\,000\,000 \cdot 0{,}391\% \cdot \frac{90}{360} = 978$
2010-05-04	0,5	$1\,000\,000 \cdot r_{1,2} \cdot \frac{90}{360}$	
2010-08-04	0,75	$1\,000\,000 \cdot r_{2,3} \cdot \frac{90}{360}$	
2010-11-04	1	$1\,000\,000 \cdot r_{3,4} \cdot \frac{90}{360}$	$-1 \cdot 1\,000\,000 \cdot 1{,}773\% \cdot \frac{360}{360} = = -17\,730$
2011-02-04	1,25	$1\,000\,000 \cdot r_{4,5} \cdot \frac{90}{360}$	
2011-05-04	1,5	$1\,000\,000 \cdot r_{5,6} \cdot \frac{90}{360}$	
2011-08-04	1,75	$1\,000\,000 \cdot r_{6,7} \cdot \frac{90}{360}$	
2011-11-04	2	$1\,000\,000 \cdot r_{7,8} \cdot \frac{90}{360}$	$-1 \cdot 1\,000\,000 \cdot 1{,}773\% \cdot \frac{360}{360} = = -17\,730$

Curve stressing

This position is exposed to a shift in the SEK swap spot curve. It is this curve that will be stressed in the margin calculation.

Risk parameters

The tables below list the stress levels together with the first points on the principal components for the SEK swap curve.

Stress levels

Curve	PC1	PC2	PC3
Swap	22 basis points	8 basis points	5 basis points

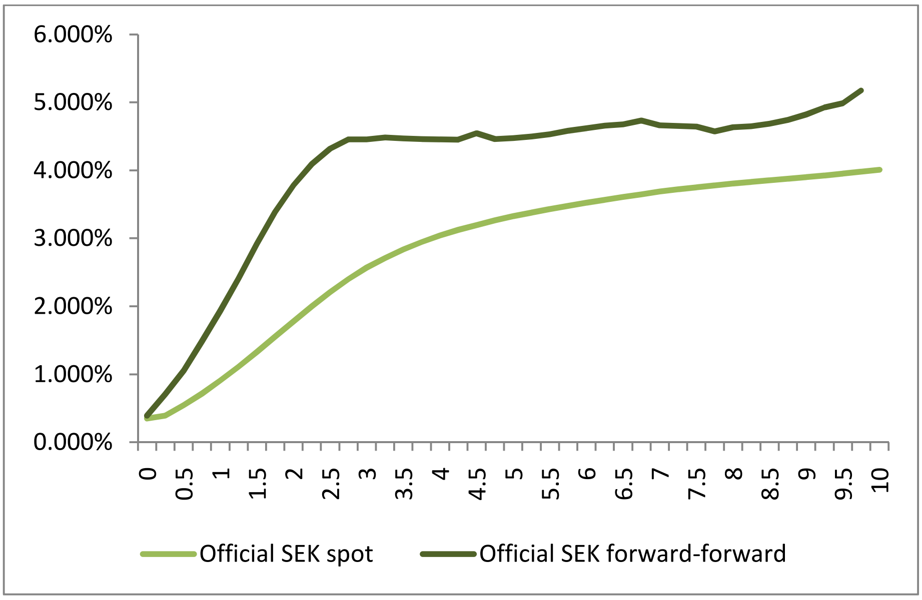
Principal components

Time to maturity	PC1	PC2	PC3
0	1	1	1
0,25	1	0,8	0,64
0,5	1	0,6	0,27
0,75	1	0,49	0,02
1	1	0,41	-0,16
1,25	1	0,34	-0,27
1,5	1	0,29	-0,33
1,75	1	0,25	-0,35
2	1	0,21	-0,35

Official curves

NOMX will, on each trading day, bootstrap official yield curves that will be used to price all cleared instruments. It is the official yield curves that will be stressed in the margin calculations. In this example it is assumed that the official SEK swap spot and forward-forward curves look as in the figure below.

Figure: Official SEK swap curves from 2009-11-04.



The table below lists the official swap spot and forward-forward rates for the maturities that are relevant to the cash flows in the swap cash flow table. Equation (2) has been used to calculate the forward-forward rates, $f(0, m_t, m_T)$, from the spot rates, $i(0, m)$. Equation (14) has then been used to convert the forward-forward rates into non-compounded forward-forward rates, r_{m_t,m_T}.

m	i(0,m)	f(0,m-1,m)	$r_{m-1,m}$
0	0,350%		
0,25	0,392%		
0,5	0,549%	$\left(\frac{(1+0{,}549\%)^{\frac{180}{360}}}{(1+0{,}392\%)^{\frac{90}{360}}}\right)^{\frac{360}{90}} - 1 = 0{,}706\%$	$\frac{360}{90}\left((1+0{,}706\%)^{\frac{90}{360}} - 1\right) = 0{,}704\%$
0,75	0,716%	$\left(\frac{(1+0{,}716\%)^{\frac{270}{360}}}{(1+0{,}549\%)^{\frac{180}{360}}}\right)^{\frac{360}{90}} - 1 = 1{,}051\%$	$\frac{360}{90}\left((1+1{,}051\%)^{\frac{90}{360}} - 1\right) = 1{,}047\%$
1	0,908%	$\left(\frac{(1+0{,}908\%)^{\frac{360}{360}}}{(1+0{,}716\%)^{\frac{270}{360}}}\right)^{\frac{360}{90}} - 1 = 1{,}486\%$	$\frac{360}{90}\left((1+1{,}486\%)^{\frac{90}{360}} - 1\right) = 1{,}478\%$
1,25	1,112%	$\left(\frac{(1+1{,}112\%)^{\frac{450}{360}}}{(1+0{,}908\%)^{\frac{360}{360}}}\right)^{\frac{360}{90}} - 1 = 1{,}932\%$	$\frac{360}{90}\left((1+1{,}932\%)^{\frac{90}{360}} - 1\right) = 1{,}918\%$
1,5	1,327%	$\left(\frac{(1+1{,}327\%)^{\frac{540}{360}}}{(1+1{,}112\%)^{\frac{450}{360}}}\right)^{\frac{360}{90}} - 1 = 2{,}409\%$	$\frac{360}{90}\left((1+2{,}409\%)^{\frac{90}{360}} - 1\right) = 2{,}388\%$
1,75	1,553%	$\left(\frac{(1+1{,}553\%)^{\frac{630}{360}}}{(1+1{,}327\%)^{\frac{540}{360}}}\right)^{\frac{360}{90}} - 1 = 2{,}920\%$	$\frac{360}{90}\left((1+2{,}92\%)^{\frac{90}{360}} - 1\right) = 2{,}889\%$
2	1,780%	$\left(\frac{(1+1{,}780\%)^{\frac{720}{360}}}{(1+1{,}553\%)^{\frac{630}{360}}}\right)^{\frac{360}{90}} - 1 = 3{,}383\%$	$\frac{360}{90}\left((1+3{,}383\%)^{\frac{90}{360}} - 1\right) = 3{,}341\%$

Stressed curves

It is only the fixed cash flows of an interest rate swap that are exposed to shifts in the swap spot curve. The worst outcome for this position is therefore that the SEK swap spot interest rates with maturities 1 and 2 years goes down. This corresponds to the scenario where the first two principal components are stressed downwards and the third principal component is stressed upwards.

Figure: SEK swap spot curve will be stressed with its principal components.

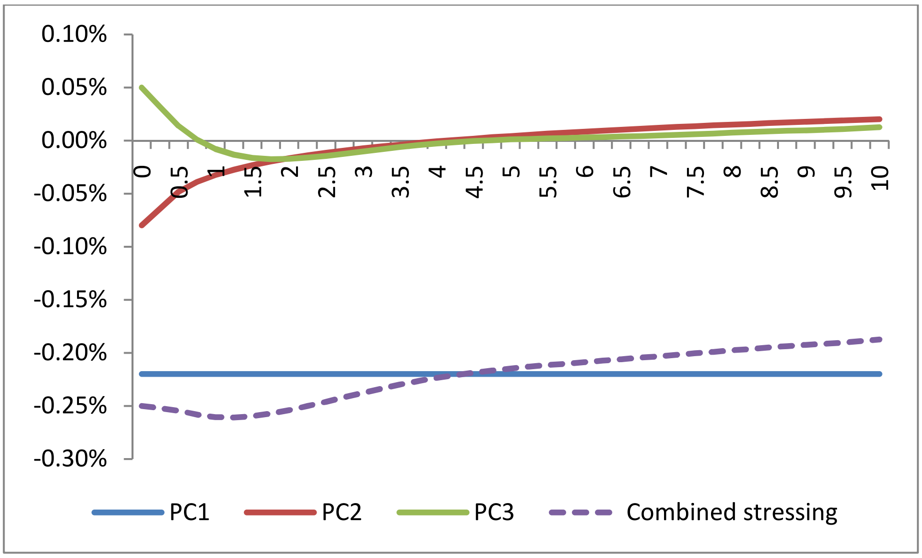
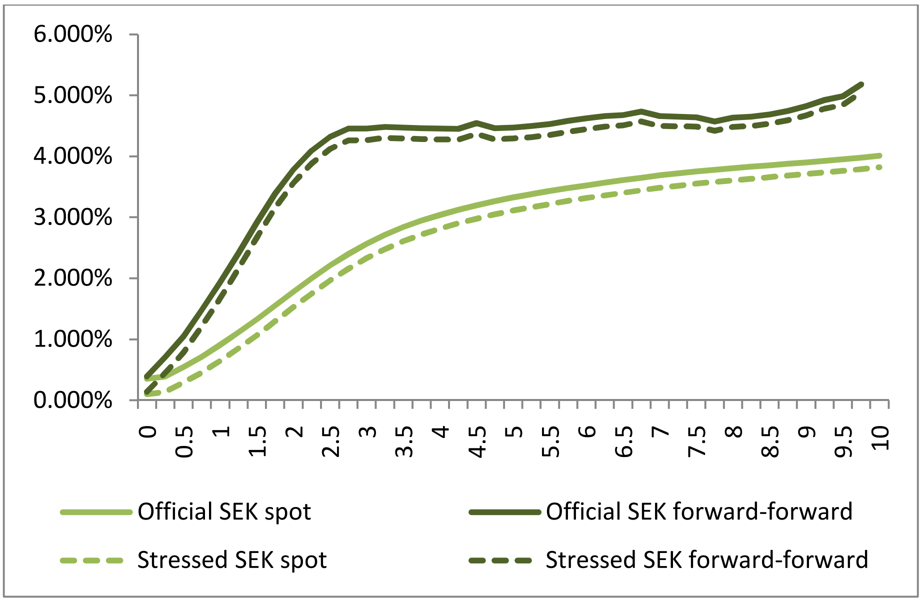


Figure: Official SEK swap curves and stressed SEK swap curve.



After the SEK swap spot rates have been stressed then Equation (2) and Equation (14) are used to update the SEK swap forward-forward rates. The table below lists the official and the stressed SEK swap rates.

m	i(0,m)	$r_{m-1,m}$	i(0,m) (stressed)	$r_{m-1,m}$ (stressed)
0	0,350%		$0{,}350\% - 0{,}22\% \cdot 1 - 0{,}08\% \cdot 1 + 0{,}05\% \cdot 1 = 0{,}100\%$	
0,25	0,392%		$0{,}392\% - 0{,}22\% \cdot 1 - 0{,}08\% \cdot 0{,}8 + 0{,}05\% \cdot 0{,}64 = 0{,}140\%$	
0,5	0,549%	0,704%	$0{,}549\% - 0{,}22\% \cdot 1 - 0{,}08\% \cdot 0{,}6 + 0{,}05\% \cdot 0{,}27 = 0{,}295\%$	0,449%
0,75	0,716%	1,047%	$0{,}716\% - 0{,}22\% \cdot 1 - 0{,}08\% \cdot 0{,}49 + 0{,}05\% \cdot 0{,}02 = 0{,}458\%$	0,783%
1	0,908%	1,478%	$0{,}908\% - 0{,}22\% \cdot 1 - 0{,}08\% \cdot 0{,}41 - 0{,}05\% \cdot 0{,}16 = 0{,}647\%$	1,210%
1,25	1,112%	1,918%	$1{,}112\% - 0{,}22\% \cdot 1 - 0{,}08\% \cdot 0{,}34 - 0{,}05\% \cdot 0{,}27 = 0{,}851\%$	1,661%
1,5	1,327%	2,387%	$1{,}327\% - 0{,}22\% \cdot 1 - 0{,}08\% \cdot 0{,}29 - 0{,}05\% \cdot 0{,}33 = 1{,}067\%$	2,137%
1,75	1,553%	2,888%	$1{,}553\% - 0{,}22\% \cdot 1 - 0{,}08\% \cdot 0{,}25 - 0{,}05\% \cdot 0{,}35 = 1{,}296\%$	2,654%
2	1,780%	3,341%	$1{,}780\% - 0{,}22\% \cdot 1 - 0{,}08\% \cdot 0{,}21 - 0{,}05\% \cdot 0{,}35 = 1{,}526\%$	3,114%

Net present value

The margin requirement is obtained by calculating the net present value of the cash flows in all cash flow tables.

In this example all cash flows are in SEK and lay in the swap cash flow table. If the net present value is calculated with the official SEK swap spot curve, then the position's market value is obtained. If, on the other hand, the net present value is calculated with the stressed SEK swap spot curve, then the position's margin requirement is obtained.

Value date	Time to maturity	SEK (floating)	SEK (floating, stressed)	SEK (fixed)
2010-02-04	0,25			978
2010-05-04	0,5	$1\,000\,000 \cdot 0{,}704\% \cdot \frac{90}{360} = 1\,760$	$1\,000\,000 \cdot 0{,}449\% \cdot \frac{90}{360} = 1\,123$	
2010-08-04	0,75	$1\,000\,000 \cdot 1{,}047\% \cdot \frac{90}{360} = 2\,618$	$1\,000\,000 \cdot 0{,}783\% \cdot \frac{90}{360} = 1\,958$	
2010-11-04	1	$1\,000\,000 \cdot 1{,}478\% \cdot \frac{90}{360} = 3\,695$	$1\,000\,000 \cdot 1{,}210\% \cdot \frac{90}{360} = 3\,025$	-17 730
2011-02-04	1,25	$1\,000\,000 \cdot 1{,}918\% \cdot \frac{90}{360} = 4\,795$	$1\,000\,000 \cdot 1{,}661\% \cdot \frac{90}{360} = 4\,153$	
2011-05-04	1,5	$1\,000\,000 \cdot 2{,}388\% \cdot \frac{90}{360} = 5\,970$	$1\,000\,000 \cdot 2{,}137\% \cdot \frac{90}{360} = 5\,343$	
2011-08-04	1,75	$1\,000\,000 \cdot 2{,}889\% \cdot \frac{90}{360} = 7\,223$	$1\,000\,000 \cdot 2{,}654\% \cdot \frac{90}{360} = 6\,635$	
2011-11-04	2	$1\,000\,000 \cdot 3{,}341\% \cdot \frac{90}{360} = 8\,353$	$1\,000\,000 \cdot 3{,}114\% \cdot \frac{90}{360} = 7\,785$	-17 730
NPV		$\frac{978}{(1+0{,}392\%)^{0{,}25}} + \frac{1\,760}{(1+0{,}549\%)^{0{,}5}} + \cdots + \frac{8\,353}{(1+1{,}780\%)^{2}} - \frac{17\,730}{(1+1{,}780\%)^{2}} = -11$		
NPV stressed		$\frac{978}{(1+0{,}140\%)^{0{,}25}} + \frac{1\,123}{(1+0{,}295\%)^{0{,}5}} + \cdots + \frac{7\,785}{(1+1{,}526\%)^{2}} - \frac{17\,730}{(1+1{,}526\%)^{2}} = -4\,353$		

Market value = SEK -11.

Margin requirement = SEK -4 353.

Example 6

Interest rate swap versus FRA

Positions

Consider a bought 2Y plain vanilla SEK fixed for floating interest rate swap that is hedged with a strip of sold FRA contracts. These positions are traded on 2009-11-02, but the margin calculation presented here is performed on 2009-11-04. In this example it has, for simplicity, been assumed that all floating rate periods have 90 days and that all fixed rate periods have 360 days.

2Y interest rate swap

t_s = 2009-11-04.
t_e = 2011-11-04.
Q = 1.
N = 1 000 000.
Side = 1.
$d_{i,i+1}$ = 90.
r_{fl} = 0,391%.
r_f = 1,773%.
$d_{f,i,i+1}$ = 360.

Strip of forward rate agreements

FRA_{12}

t_m = 2010-02-04.
Q = 1.
N = 1 000 000.
Side = -1.
$d_{1,2}$ = 90.
r_c = 0,704%.

FRA_{23}

t_m = 2010-05-04.
Q = 1.
N = 1 000 000.
Side = -1.
$d_{2,3}$ = 90.
r_c = 1,047%.

FRA_{34}

t_m = 2010-08-04.
Q = 1.
N = 1 000 000.
Side = -1.
$d_{3,4}$ = 90.
r_c = 1,478%.

FRA_{45}

t_m	=	2010-11-04.
Q	=	1.
N	=	1 000 000.
Side	=	-1.
$d_{4,5}$	=	90.
r_c	=	1,918%.

FRA_{56}

t_m	=	2011-02-04.
Q	=	1.
N	=	1 000 000.
Side	=	-1.
$d_{5,6}$	=	90.
r_c	=	2,388%.

FRA_{67}

t_m	=	2011-05-04.
Q	=	1.
N	=	1 000 000.
Side	=	-1.
$d_{6,7}$	=	90.
r_c	=	2,889%.

FRA_{78}

t_m	=	2011-08-04.
Q	=	1.
N	=	1 000 000.
Side	=	-1.
$d_{7,8}$	=	90.
r_c	=	3,341%.

Cash flow tables

2Y interest rate swap

Equation (13) is used to insert the floating cash flows into the FRA and swap cash flow table. Equations (15) – (16) are used to insert the fixed cash flows into the FRA and swap cash flow table. It should be noted that the value of the floating cash flows will be updated when the swap spot curve changes.

Strip of forward rate agreements

Equations (17) – (18) are used to insert the FRA contracts into the FRA and swap cash flow tables. The profit and loss from a FRA contract is a floating cash flow, and hence it will be updated when the swap spot curve changes.

FRA and swap cash flow table (swap curve)

Value date	m	SEK (floating)	SEK (fixed)
2010-02-04	0,25	$\frac{1\,000\,000 \cdot (0{,}704\% - r_{1,2}) \cdot \frac{90}{360}}{(1 + r_{1,2} * \frac{90}{360})}$	$1\,000\,000 \cdot 0{,}391\% \cdot \frac{90}{360}$ $= 978$
2010-05-04	0,5	$\frac{1\,000\,000 \cdot \left(1{,}047\% - r_{2,3}\right) \cdot \frac{90}{360}}{(1 + r_{2,3} * \frac{90}{360})}$ $+1\,000\,000 \cdot r_{1,2} \cdot \frac{90}{360}$	
2010-08-04	0,75	$\frac{1\,000\,000 \cdot \left(1{,}478\% - r_{3,4}\right) \cdot \frac{90}{360}}{(1 + r_{3,4} * \frac{90}{360})}$ $+1\,000\,000 \cdot r_{2,3} \cdot \frac{90}{360}$	
2010-11-04	1	$\frac{1\,000\,000 \cdot \left(1{,}918\% - r_{4,5}\right) \cdot \frac{90}{360}}{(1 + r_{4,5} * \frac{90}{360})}$ $+1\,000\,000 \cdot r_{3,4} \cdot \frac{90}{360}$	$-1\,000\,000 \cdot 1{,}773\% \cdot \frac{360}{360}$ $= -17\,730$
2011-02-04	1,25	$\frac{1\,000\,000 \cdot \left(2{,}388\% - r_{5,6}\right) \cdot \frac{90}{360}}{(1 + r_{5,6} * \frac{90}{360})}$ $+1\,000\,000 \cdot r_{4,5} \cdot \frac{90}{360}$	
2011-05-04	1,5	$\frac{1\,000\,000 \cdot \left(2{,}889\% - r_{6,7}\right) \cdot \frac{90}{360}}{(1 + r_{6,7} * \frac{90}{360})}$ $+1\,000\,000 \cdot r_{5,6} \cdot \frac{90}{360}$	
2011-08-04	1,75	$\frac{1\,000\,000 \cdot \left(3{,}341\% - r_{7,8}\right) \cdot \frac{90}{360}}{(1 + r_{7,8} * \frac{90}{360})}$ $+1\,000\,000 \cdot r_{6,7} \cdot \frac{90}{360}$	
2011-11-04	2	$1\,000\,000 \cdot r_{7,8} \cdot \frac{90}{360}$	$-1\,000\,000 \cdot 1{,}773\% \cdot \frac{360}{360}$ $= -17\,730$

Curve stressing

This position is exposed to a shift in the SEK swap spot curve. It is this curve that will be stressed in the margin calculation.

Risk parameters

The tables below list the stress levels together with the first points on the principal components for the SEK swap curve.

Stress levels

Curve	PC1	PC2	PC3
Swap	22 basis points	8 basis points	5 basis points

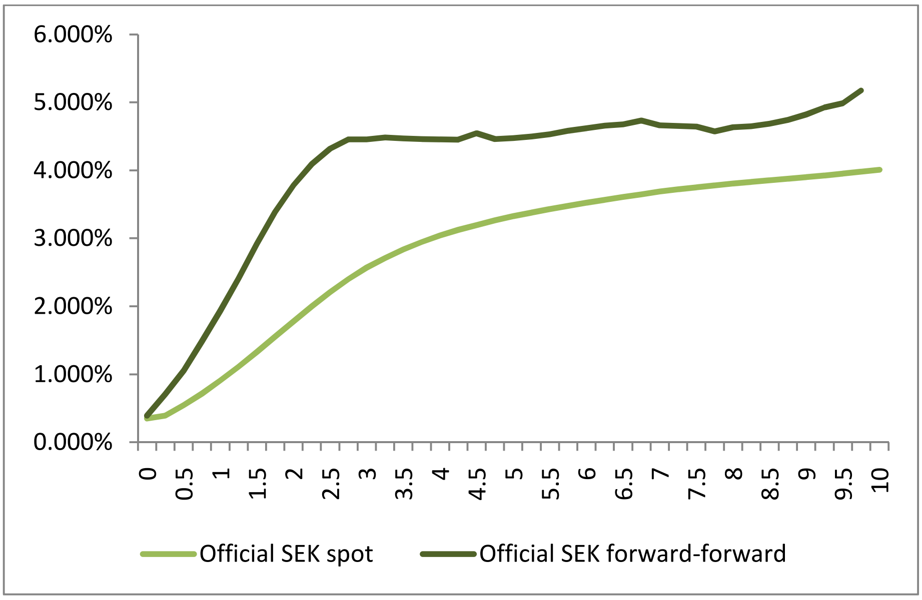
Principal components

Time to maturity	PC1	PC2	PC3
0	1	1	1
0,25	1	0,8	0,64
0,5	1	0,6	0,27
0,75	1	0,49	0,02
1	1	0,41	-0,16
1,25	1	0,34	-0,27
1,5	1	0,29	-0,33
1,75	1	0,25	-0,35
2	1	0,21	-0,35

Official curves

NOMX will, on each trading day, bootstrap official yield curves that will be used to price all cleared instruments. It is the official yield curves that will be stressed in the margin calculations. In this example it is assumed that the official SEK swap spot and forward-forward curves look as in the figure below.

Figure: Official SEK swap curves from 2009-11-04.



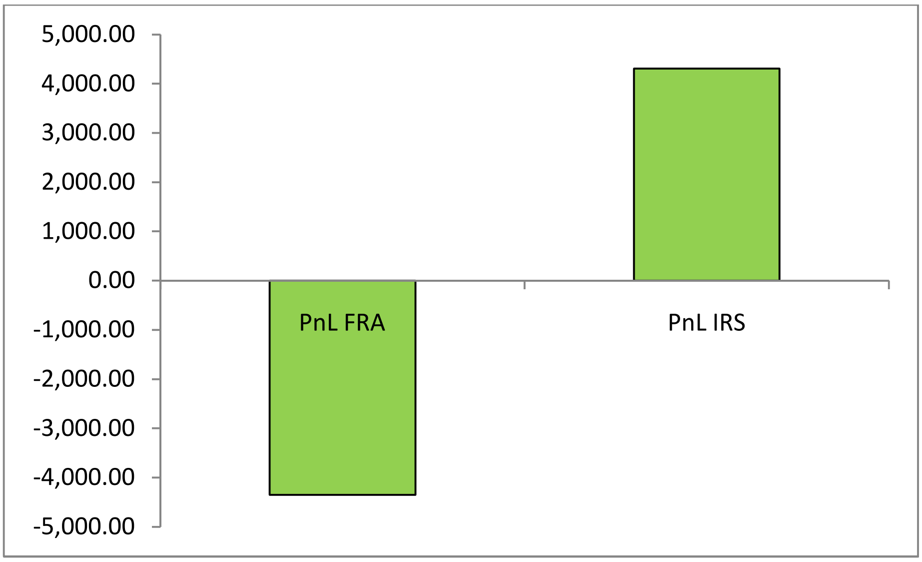
The table below lists the official swap spot and forward-forward rates for the maturities that are relevant to the cash flows in the swap cash flow table. Equation (2) has been used to calculate the forward-forward rates, $f(0, m_t, m_T)$, from the spot rates, $i(0, m)$. Equation (14) has then been used to convert the forward-forward rates into non-compounded forward-forward rates, r_{m_t,m_T}.

m	i(0,m)	f(0,m-1,m)	$r_{m-1,m}$
0	0,350%		
0,25	0,392%		
0,5	0,549%	$\left(\frac{(1+0{,}549\%)^{\frac{180}{360}}}{(1+0{,}392\%)^{\frac{90}{360}}}\right)^{\frac{360}{90}} - 1 = 0{,}706\%$	$\frac{360}{90}\left((1+0{,}706\%)^{\frac{90}{360}} - 1\right) = 0{,}704\%$
0,75	0,716%	$\left(\frac{(1+0{,}716\%)^{\frac{270}{360}}}{(1+0{,}549\%)^{\frac{180}{360}}}\right)^{\frac{360}{90}} - 1 = 1{,}051\%$	$\frac{360}{90}\left((1+1{,}051\%)^{\frac{90}{360}} - 1\right) = 1{,}047\%$
1	0,908%	$\left(\frac{(1+0{,}908\%)^{\frac{360}{360}}}{(1+0{,}716\%)^{\frac{270}{360}}}\right)^{\frac{360}{90}} - 1 = 1{,}486\%$	$\frac{360}{90}\left((1+1{,}486\%)^{\frac{90}{360}} - 1\right) = 1{,}478\%$
1,25	1,112%	$\left(\frac{(1+1{,}112\%)^{\frac{450}{360}}}{(1+0{,}908\%)^{\frac{360}{360}}}\right)^{\frac{360}{90}} - 1 = 1{,}932\%$	$\frac{360}{90}\left((1+1{,}932\%)^{\frac{90}{360}} - 1\right) = 1{,}918\%$
1,5	1,327%	$\left(\frac{(1+1{,}327\%)^{\frac{540}{360}}}{(1+1{,}112\%)^{\frac{450}{360}}}\right)^{\frac{360}{90}} - 1 = 2{,}409\%$	$\frac{360}{90}\left((1+2{,}409\%)^{\frac{90}{360}} - 1\right) = 2{,}388\%$
1,75	1,553%	$\left(\frac{(1+1{,}553\%)^{\frac{630}{360}}}{(1+1{,}327\%)^{\frac{540}{360}}}\right)^{\frac{360}{90}} - 1 = 2{,}920\%$	$\frac{360}{90}\left((1+2{,}920\%)^{\frac{90}{360}} - 1\right) = 2{,}889\%$
2	1,780%	$\left(\frac{(1+1{,}780\%)^{\frac{720}{360}}}{(1+1{,}553\%)^{\frac{630}{360}}}\right)^{\frac{360}{90}} - 1 = 3{,}383\%$	$\frac{360}{90}\left((1+3{,}383\%)^{\frac{90}{360}} - 1\right) = 3{,}341\%$

Stressed curves

The FRA contracts are traded at the official forward-forward rates. The worst outcome for the sold FRA contracts is that the SEK swap forward-forward curve increases and the worst outcome for the interest rate swap is that the SEK swap spot curve drops. The FRA contracts will therefore generate a profit when the interest rate swap generates a loss and vice versa. This combined position can therefore be considered to be a hedged position.

Figure: Profit and loss for the sold FRA strip and the bought interest rate swap as the SEK swap spot curve is stressed with and upward parallel shift of 22 basis points.



For this combined position it turns out that the Swap contract is slightly more sensitive to an interest rate change compared to the FRA contracts. This implies that the worst outcome is that the SEK swap spot curve decreases. This corresponds to the scenario when the first two principal components are stressed downwards and the third principal component is stressed upwards.

Figure: SEK swap spot curve will be stressed with its principal components.

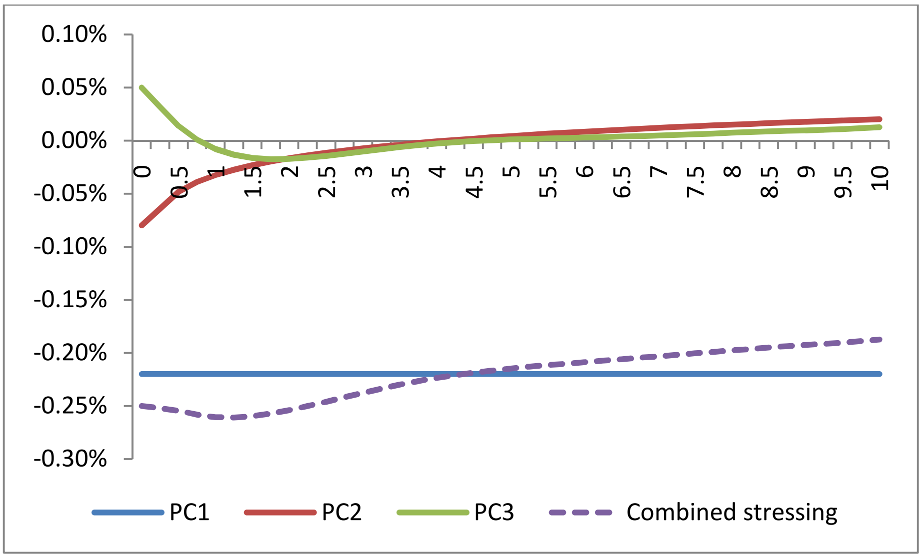
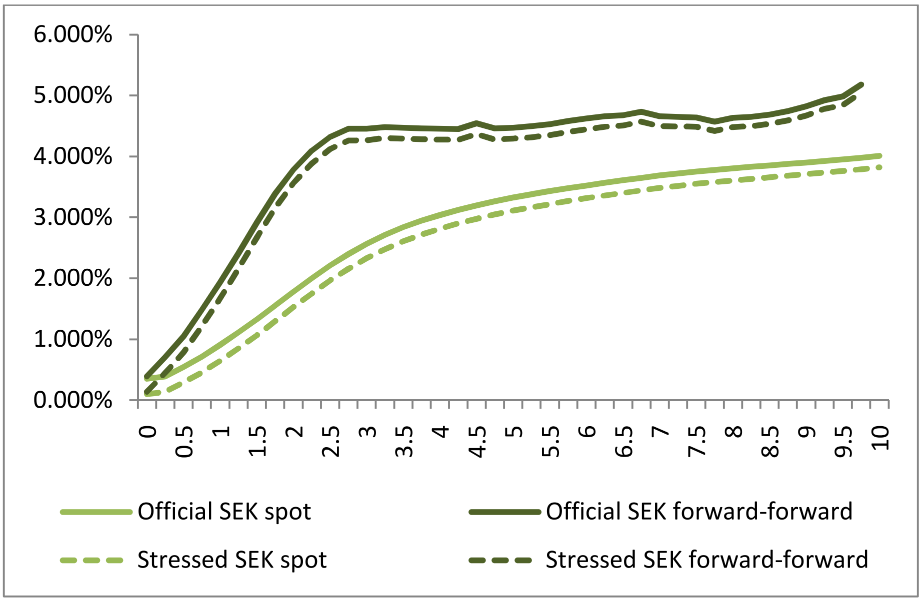


Figure: Official SEK swap curves and stressed SEK swap curve.



After the SEK swap spot rates have been stressed then Equation (2) and Equation (14) are used to update the SEK swap forward-forward rates. The table below list the official and the stressed SEK swap rates.

m	i(0,m)	$r_{m-1,m}$	i(0,m) (stressed)	$r_{m-1,m}$ (stressed)
0	0,350%		$0{,}350\% - 0{,}22\% \cdot 1 - 0{,}08\% \cdot 1 + 0{,}05\% \cdot 1 = 0{,}100\%$	
0,25	0,392%		$0{,}392\% - 0{,}22\% \cdot 1 - 0{,}08\% \cdot 0{,}8 + 0{,}05\% \cdot 0{,}64 = 0{,}140\%$	
0,5	0,549%	0,704%	$0{,}549\% - 0{,}22\% \cdot 1 - 0{,}08\% \cdot 0{,}6 + 0{,}05\% \cdot 0{,}27 = 0{,}295\%$	0,449%
0,75	0,716%	1,047%	$0{,}716\% - 0{,}22\% \cdot 1 - 0{,}08\% \cdot 0{,}49 + 0{,}05\% \cdot 0{,}02 = 0{,}458\%$	0,783%
1	0,908%	1,478%	$0{,}908\% - 0{,}22\% \cdot 1 - 0{,}08\% \cdot 0{,}41 - 0{,}05\% \cdot 0{,}16 = 0{,}647\%$	1,210%
1,25	1,112%	1,918%	$1{,}112\% - 0{,}22\% \cdot 1 - 0{,}08\% \cdot 0{,}34 - 0{,}05\% \cdot 0{,}27 = 0{,}851\%$	1,661%
1,5	1,327%	2,387%	$1{,}327\% - 0{,}22\% \cdot 1 - 0{,}08\% \cdot 0{,}29 - 0{,}05\% \cdot 0{,}33 = 1{,}067\%$	2,137%
1,75	1,553%	2,888%	$1{,}553\% - 0{,}22\% \cdot 1 - 0{,}08\% \cdot 0{,}25 - 0{,}05\% \cdot 0{,}35 = 1{,}296\%$	2,654%
2	1,780%	3,341%	$1{,}780\% - 0{,}22\% \cdot 1 - 0{,}08\% \cdot 0{,}21 - 0{,}05\% \cdot 0{,}35 = 1{,}526\%$	3,114%

Net present value

The margin requirement is obtained by calculating the net present value of the cash flows in the cash flow table. In this example all cash flows are in SEK and are exposed to the swap curve. If the net present value is calculated with the official SEK swap spot curve, then the position's market value is obtained. If, on the other hand, the net present value is calculated with the stressed SEK swap spot curve, then the position's margin requirement is obtained.

m	SEK (floating)	SEK (floating, stressed)	SEK (fixed)
0,25	$\frac{1\,000\,000 \cdot (0{,}704\% - 0{,}704\%) \cdot \frac{90}{360}}{(1 + 0{,}704\% * \frac{90}{360})} = 0$	$\frac{1\,000\,000 \cdot (0{,}704\% - 0{,}449\%) \cdot \frac{90}{360}}{(1 + 0{,}449\% * \frac{90}{360})} = 637$	978
0,5	$\frac{1\,000\,000 \cdot (1{,}047\% - 1{,}047\%) \cdot \frac{90}{360}}{(1 + 1{,}047\% * \frac{90}{360})} + 1\,000\,000 \cdot 0{,}704\% \cdot \frac{90}{360} = 1\,760$	$\frac{1\,000\,000 \cdot (1{,}047\% - 0{,}783\%) \cdot \frac{90}{360}}{(1 + 0{,}783\% * \frac{90}{360})} + 1\,000\,000 \cdot 0{,}449\% \cdot \frac{90}{360} = 1\,782$	
0,75	$\frac{1\,000\,000 \cdot (1{,}478\% - 1{,}478\%) \cdot \frac{90}{360}}{(1 + 1{,}478\% * \frac{90}{360})} + 1\,000\,000 \cdot 1{,}047\% \cdot \frac{90}{360} = 2\,618$	$\frac{1\,000\,000 \cdot (1{,}478\% - 1{,}210\%) \cdot \frac{90}{360}}{(1 + 1{,}210\% * \frac{90}{360})} + 1\,000\,000 \cdot 0{,}783\% \cdot \frac{90}{360} = 2\,626$	
1	$\frac{1\,000\,000 \cdot (1{,}918\% - 1{,}918\%) \cdot \frac{90}{360}}{(1 + 1{,}918\% * \frac{90}{360})} + 1\,000\,000 \cdot 1{,}478\% \cdot \frac{90}{360} = 3\,695$	$\frac{1\,000\,000 \cdot (1{,}918\% - 1{,}661\%) \cdot \frac{90}{360}}{(1 + 1{,}661\% * \frac{90}{360})} + 1\,000\,000 \cdot 1{,}210\% \cdot \frac{90}{360} = 3\,665$	-17 730
1,25	$\frac{1\,000\,000 \cdot (2{,}388\% - 2{,}388\%) \cdot \frac{90}{360}}{(1 + 2{,}388\% * \frac{90}{360})} + 1\,000\,000 \cdot 1{,}918\% \cdot \frac{90}{360} = 4\,795$	$\frac{1\,000\,000 \cdot (2{,}388\% - 2{,}137\%) \cdot \frac{90}{360}}{(1 + 2{,}137\% * \frac{90}{360})} + 1\,000\,000 \cdot 1{,}661\% \cdot \frac{90}{360} = 4\,777$	
1,5	$\frac{1\,000\,000 \cdot (2{,}889\% - 2{,}889\%) \cdot \frac{90}{360}}{(1 + 2{,}889\% * \frac{90}{360})} + 1\,000\,000 \cdot 2{,}388\% \cdot \frac{90}{360} = 5\,970$	$\frac{1\,000\,000 \cdot (2{,}889\% - 2{,}654\%) \cdot \frac{90}{360}}{(1 + 2{,}654\% * \frac{90}{360})} + 1\,000\,000 \cdot 2{,}137\% \cdot \frac{90}{360} = 5\,926$	
1,75	$\frac{1\,000\,000 \cdot (3{,}341\% - 3{,}341\%) \cdot \frac{90}{360}}{(1 + 3{,}341\% * \frac{90}{360})} + 1\,000\,000 \cdot 2{,}889\% \cdot \frac{90}{360} = 7\,223$	$\frac{1\,000\,000 \cdot (3{,}341\% - 3{,}114\%) \cdot \frac{90}{360}}{(1 + 3{,}114\% * \frac{90}{360})} + 1\,000\,000 \cdot 2{,}654\% \cdot \frac{90}{360} = 7\,199$	
2	$1\,000\,000 \cdot 3{,}341\% \cdot \frac{90}{360} = 8\,353$	$1\,000\,000 \cdot 3{,}114\% \cdot \frac{90}{360} = 7\,785$	-17 730
NPV	$-\frac{0}{(1+0{,}392\%)^{0{,}25}} + \frac{978}{(1+0{,}392\%)^{0{,}25}} + \cdots + \frac{8\,353}{(1+1{,}780\%)^{2}} - \frac{17\,730}{(1+1{,}780\%)^{2}} = -11$		
NPV stressed	$\frac{637}{(1+0{,}140\%)^{0{,}25}} + \frac{978}{(1+0{,}140\%)^{0{,}25}} + \cdots + \frac{7785}{(1+1{,}526\%)^{2}} - \frac{17\,730}{(1+1{,}526\%)^{2}} = -15$		

Market value = SEK -11.

Margin requirement = SEK -15.

It should be noted that this margin requirement is less than one percent of the FRA contracts and the interest rate swaps combined naked margins.

EXAMPLE 7

FRA PORTFOLIO VERSUS RIBA PORTFOLIO

POSITIONS

Consider a bought 1Y strip of RIBA futures that is partly hedged with a 1Y strip of sold FRA contracts. These positions are traded on 2011-08-01, but the margin calculation presented here is performed on 2011-09-09. This means that for the FRAs, it is the last settlement price, from 2011-08-31, that will determine their current market value. The daily settled RIBA futures have a market value of zero after each end of day. Here we use the RIBA fixing prices from 2011-09-09 as a departing point when calculating the possible shifts in market value (i.e. the margin requirement). In this example it has, for simplicity, been assumed that all floating rate periods have 90 days and that all fixed rate periods have 360 days. Please note that the expiration month codes differ between a RIBA future and a FRA on the same underlying time period.

STRIP OF RIBA FUTURES

RIBA11Z

t_m = 2011-12-21.

Q = 2.
N = 1 000 000.
Side = 1.
$d_{1,2}$ = 90.
r_c = 1,93%.

RIBA12H

t_m = 2012-03-21.
Q = 2.
N = 1 000 000.
Side = 1.
$d_{2,3}$ = 90.
r_c = 1,635%.

RIBA12M

tm = 2012-06-20.
Q = 2.
N = 1 000 000.
Side = 1.
d3,4 = 90.
rc = 1,35%.

RIBA12U

t_m = 2012-09-19.
Q = 2.
N = 1 000 000.
Side = 1.
$d_{3,4}$ = 90.

r_c = 1,19%.

STRIP OF FORWARD RATE AGREEMENTS

FRA11U

t_m = 2011-09-21.
Q = 1.
N = 1 000 000.
Side = -1.
$d_{1,2}$ = 90.
r_c = 2,603%.

FRA11X

t_m = 2011-12-21.
Q = 1.
N = 1 000 000.
Side = -1.
$d_{2,3}$ = 90.
r_c = 2,413%.

FRA12O

t_m = 2012-03-21.
Q = 1.
N = 1 000 000.
Side = -1.
$d_{3,4}$ = 90.
r_c = 2,24%.

FRA12R

t_m = 2012-06-20.
Q = 1.
N = 1 000 000.
Side = -1.
$d_{4,5}$ = 90.
r_c = 2,133%.

Cash flow tables

Strip of RIBA Futures

Equations (22) – (24) are used to insert the RIBA futures contracts into the RIBA cash flow tables. The profit and loss from a RIBA futures contract is a floating cash flow, and hence it will be updated when the RIBA curve changes. Note that no discounting of cash flows will take place, the stressed NPV of a RIBA future is determined solely by the forecasted floating cash flow.

RIBA cash flow table (RIBA curve)

Value date	m	SEK (floating)
2011-12-21	0,2822	$2\,000\,000 \cdot (-1{,}93\% + r_{2011-09-21,2011-12-21}) \cdot 90/360$
2012-03-21	0,5315	$2\,000\,000 \cdot (-1{,}635\% + r_{2011-12-21.2012-03-21}) \cdot 90/360$
2012-06-20	0,7808	$2\,000\,000 \cdot (-1{,}35\% + r_{2012-03-21,2012-06-20}) \cdot 90/360$
2012-09-19	1,0301	$2\,000\,000 \cdot (-1{,}19\% + r_{2012-06-20,2012-09-19}) \cdot 90/360$

Strip of forward rate agreements

Equations (17) – (18) are used to insert the FRA contracts into the FRA and swap cash flow tables. The profit and loss from a FRA contract is a floating cash flow, and hence it will be updated when the swap spot curve changes.

FRA and swap cash flow table (swap curve)

Value date	m	SEK (floating)
2011-09-21	0,0329	$\dfrac{1\,000\,000 \cdot (2{,}603\% - r_{2011-09-21,2011-12-21}) \cdot \frac{90}{360}}{(1 + r_{2011-09-21,2011-12-21} * \frac{90}{360})}$
2011-12-21	0,2822	$\dfrac{1\,000\,000 \cdot (2{,}413\% - r_{2011-12-21,2012-03-21}) \cdot \frac{90}{360}}{(1 + r_{2011-12-21,2012-03-21} * \frac{90}{360})}$
2012-03-21	0,5315	$\dfrac{1\,000\,000 \cdot (2{,}24\% - r_{2012-03-21,2012-06-20}) \cdot \frac{90}{360}}{(1 + r_{2012-03-21,2012-06-20} * \frac{90}{360})}$
2012-06-20	0,7808	$\dfrac{1\,000\,000 \cdot (2{,}133\% - r_{2012-06-20,2012-09-19}) \cdot \frac{90}{360}}{(1 + r_{2012-06-20,2012-09-19} * \frac{90}{360})}$

Curve stressing

This position is exposed to shifts in the SEK swap spot curve and in the RIBA spot curve. These curves will be stressed in the margin calculation, and their inter curve correlation will influence the way in which the total portfolio is margined.

Risk parameters

The tables below list the stress levels together with the first eight quarters on the principal components for the SEK swap curve. When estimating the principal components' levels for other points on the time axis a linear interpolation is used.

Stress levels

Curve	PC1	PC2	PC3
Swap	22 basis points	8 basis points	5 basis points
RIBA	22 basis points	8 basis points	5 basis points

Principal components

Time to maturity	PC1	PC2	PC3
0	1	1	1
0,25	1	0,8	0,64
0,5	1	0,6	0,27
0,75	1	0,49	0,02
1	1	0,41	-0,16
1,25	1	0,34	-0,27
1,5	1	0,29	-0,33
1,75	1	0,25	-0,35
2	1	0,21	-0,35
2,25	1	0,18	-0,32

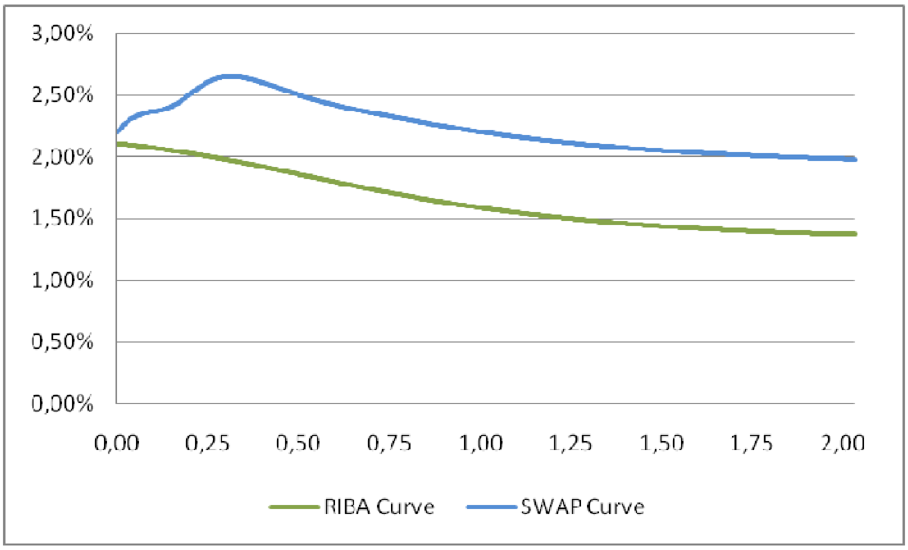
Correlation

In this example the scanning range in each principal component is divided into 5 steps, yielding a total of 5 * 5 * 5 = 125 different scenarios for which the shift in market value is calculated. We use a correlation cube of size 3 * 3 * 3 between the two curves to account for their co-variation.

Official curves

NOMX will, on each trading day, bootstrap official yield curves that will be used to price all cleared instruments. It is the official yield curves that will be stressed in the margin calculations. In this example it is assumed that the official SEK swap spot and RIBA spot curves look as in the figure below.

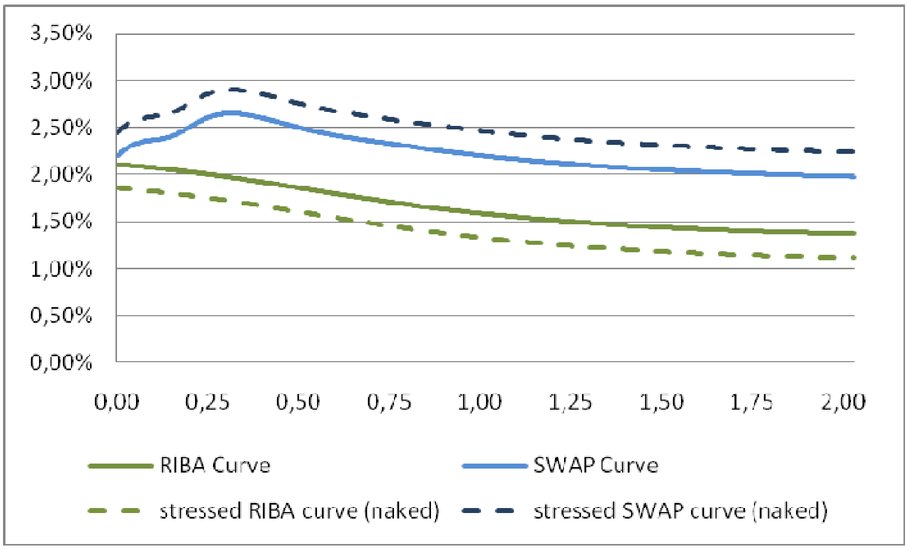
Figure: Official SEK swap & RIBA curves from 2011-09-09.



STRESSED CURVES

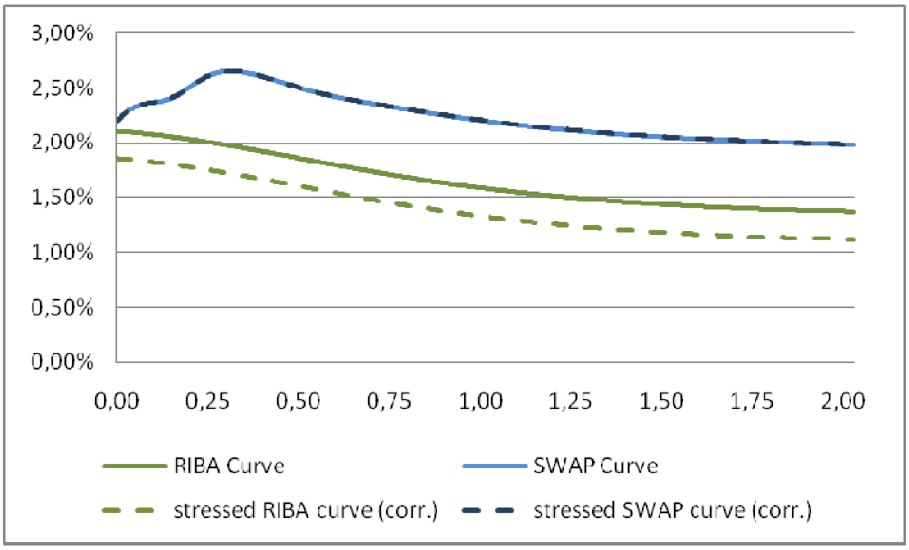
The long position (pay contracted rate) in the RIBA strip is exposed to a downward shift of the RIBA curve. The short position (receive contracted rate) in the FRA strip is exposed to an upward shift in the SEK Swap curve. If no correlation benefits were offered between the two curves they would be stressed in opposite directions in the margin calculation. The effect is illustrated below.

Figure: Curve stress that would result if no correlation was configured



As mentioned before, however, in this case there is a modeled correlation between the two curves. This would be a result of NOMX RM observing correlation between the two curves in historical time series. The correlation cube is set to 3*3*3, and as the total scenario cubes is of size 5*5*5, that means that we will margin our positions across the 3*3*3 sub-space of scenarios that yields the lowest margin. In this case it results in the RIBA curve being stressed as if it was a naked position. This was expected, since the RIBA-strip is twice the size as the FRA-strip and has exactly the same risk parameters, and thus carries larger risk. One can say that the RIBA positions will drive the margin scenario. The worst curve scenario for the SEK Swap curve which lies within the same 3*3*3 cube, is that no curve stress occurs.

Figure: Curve stress with correlation benefits taken into account



NET PRESENT VALUE

The margin requirement is obtained by calculating the net present value of the cash flows in the cash flow tables for all scenarios, and identifying the one which yields the worst stressed NPV.

The RIBA strip has an unstressed NPV of 0 by default since the contracts are subject to daily settlement. The FRA strip is subject to monthly settlement, and has a small NPV.

The stressed RIBA curve gives us a stressed NPV for the strip of RIBA futures. Since the NPV of the FRA strips isn't stressed in the combination of scenarios that yields the worst result, given the correlation cube of size 3*3*3, the margin is simply the NPV of the FRA strip plus the stressed NPV of the RIBA futures

m	FRA strip SEK (floating)	RIBA strip SEK (floating, stressed)
0,0329	=135	
0,2822	=305	= - 1350

0,5315	$\dfrac{1\,000\,000 \cdot (2{,}24\% - 1{,}93\%) \cdot \frac{90}{360}}{(1 + 1{,}93\% * \frac{90}{360})}$ =523	$2\,000\,000 \cdot (-1{,}635\% + 1{,}37\%) \cdot \dfrac{90}{360}$ = - 1325
0,7808	$\dfrac{1\,000\,000 \cdot (2{,}133\% - 1{,}768\%) \cdot \frac{90}{360}}{(1 + 1{,}768\% * \frac{90}{360})}$ =633	$2\,000\,000 \cdot (-1{,}35\% + 1{,}08\%) \cdot \dfrac{90}{360}$ = -1350
1,0301		$2\,000\,000 \cdot (-1{,}19\% + 0{,}92\%) \cdot \dfrac{90}{360}$ = -1350

NPV RIBA (unstressed) $= 0$

NPV FRA (unstressed) =

$$\frac{135}{(1+2,29\%)^{0,0329}} + \frac{305}{(1+2,64\%)^{0,2822}} + \frac{523}{(1+2,47\%)^{0,5315}} + \frac{633}{(1+2,31\%)^{0,7808}}$$

= 1575

NPV RIBA (stressed) = -1350 - 1325 – 1350 - 1350 = -5375

Market value = SEK 1575

Margin requirement = SEK -3800.

Example 8

Future contracts with daily settlement

Positions

Consider the below portfolio of 100 bought 3MSTIBZ1 (Futures contract on the 3 month STIBOR). The future has daily settlement so the market value end of day will be equal to zero. The position is traded on 2011-09-02, but the margin calculation presented here is performed on 2011-09-22.

3MSTIBZ1

t_m = 2011-12-21.
Q = 100.
N = 1 000 000.
Side = 1.
$d_{1,2}$ = 90.
P_c = 97,559
r_c = 2,441%

Cash flows

Equations (25) and (26) is used to insert the STIBOR futures contracts into the SEK Swap cash flow tables. The profit and loss from a STIBOR future contract is a floatin cash flow, and hence it will be updated when the SEK Swap curve changes. Note that no discounting of cash flows will take place, the stressed NPV of the STIBOR future is determined solely by the forecasted floating cash flows.

$$\boldsymbol{PnL}_{3\text{MSTIBZ1}}\left(\boldsymbol{r}_{\boldsymbol{m},\boldsymbol{m}+\mathbf{1}},\boldsymbol{r}_{\boldsymbol{c}}\right)$$

$$= \mathbf{1}\cdot\mathbf{100}\cdot\mathbf{1\,000\,000}\cdot(2{,}441\% - \boldsymbol{r}_{\mathbf{2011-12-21,2012-03-21}})\cdot\frac{90}{\mathbf{360}}$$

The floating cash flow will be decided by the forward-forward rate from the curve.

Curve stressing

This position is exposed to a shift in the SEK swap spot curve. It is this curve that will be stressed in the margin calculation.

Risk parameters

The tables below list the stress levels together with the first points on the principal components for the SEK swap curve.

Stress levels

Curve	PC1	PC2	PC3
Swap	22 basis points	8 basis points	5 basis points

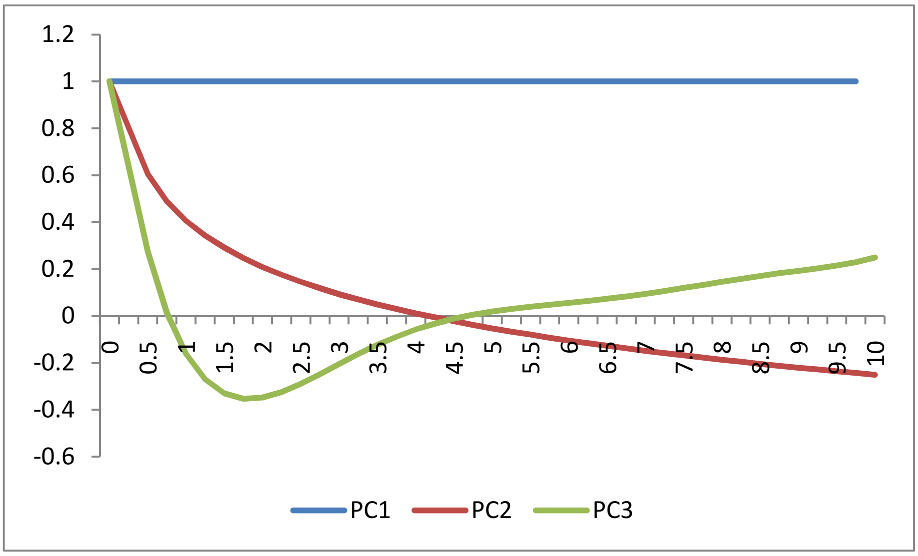
Principal components

Time to maturity	PC1	PC2	PC3
0	1	1	1
0,25	1	0,8	0,64

0,5	1	0,6	0,27
0,75	1	0,49	0,02
1	1	0,41	-0,16
1,25	1	0,34	-0,27
1,5	1	0,29	-0,33
1,75	1	0,25	-0,35
2	1	0,21	-0,35

The shape of the SEK swap curve's principal components is shown in the figure below.

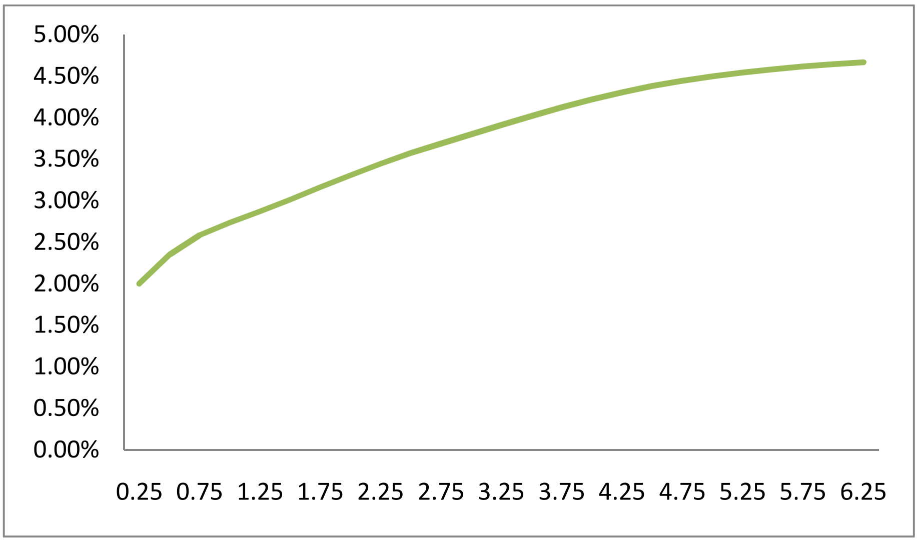
Figure: Shape of the SEK swap curve's principal components.



Official curves

NOMX will, on each trading day, bootstrap official yield curves that will be used to price all cleared instruments. It is the official yield curves that will be stressed in the margin calculations. In this example it is assumed that the official SEK swap spot curve look as in the figure below.

Figure: Swap curve



The table below lists the official Swap spot rates for the time to maturities that are relevant to the cash flows.

Value date	m	i(0,m)	f(0,m-1,m)
2011-12-21	0,246575	2,4676%	
2012-03-21	0,49589	2,4691%	$\left(\frac{(1+2{,}4691\%)^{0{,}49589}}{(1+2{,}4676\%)^{0{,}246575}}\right)^{\frac{1}{0{,}249315}} - 1 = 2{,}47071\%$

Equation (14) has been used to convert the forward-forward rate into non-compounded forward-forward rate.

Value date	m	f(0,m-1,m)	$r_{m-1,m}$
2012-03-21	0,49589	2,47071%	$\frac{360}{90}\left((1+2{,}47071\%)^{(0{,}49589-0{,}246575)} - 1\right) = 2{,}441\%$

STRESSED CURVES

The worst scenario for the floating cash flow will be that the forward-forward rate goes up. The worst outcome will be the scenario where the first two principal components are stressed upwards and the third principal component is stressed downwards.

Figure: The worst scenario is when the Swap curve is stressed upward.

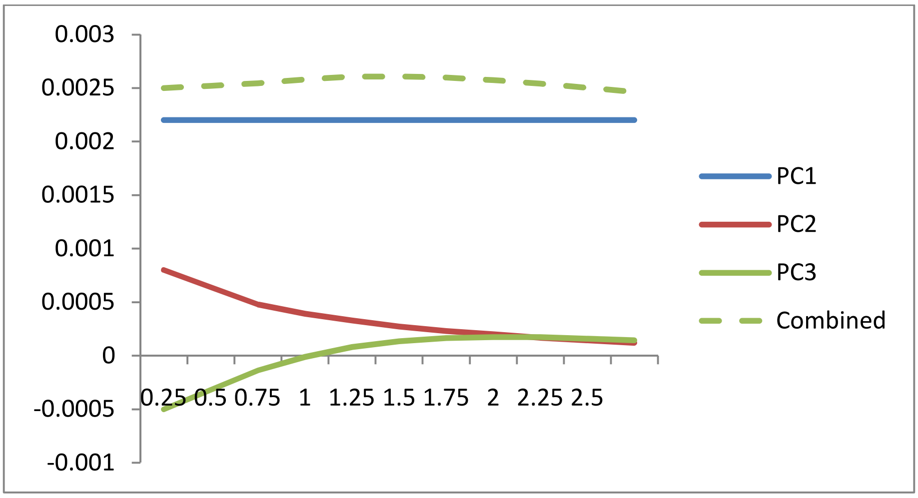
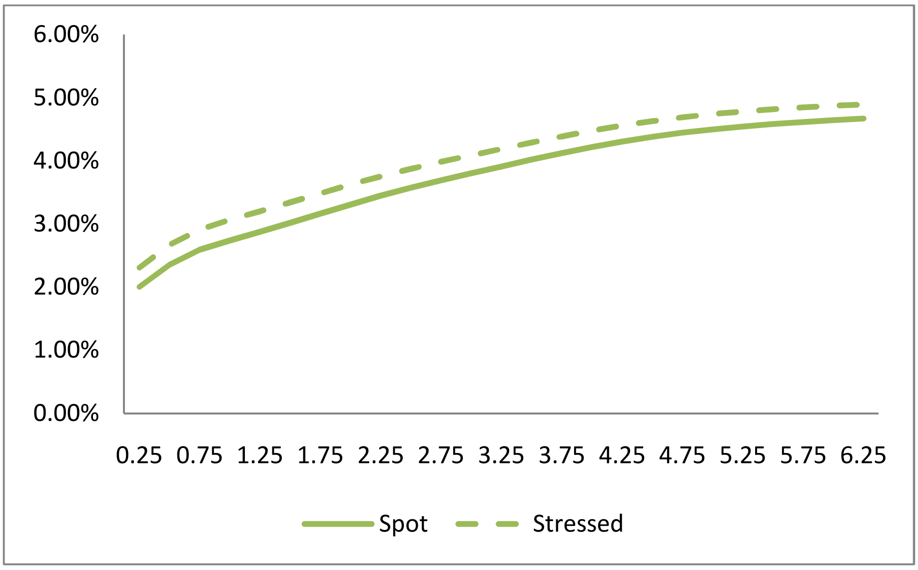


Figure: Official Swap curve and stressed Swap curve



NOMX defines the principal components in a predefined number of nodes. The distance between each node is in this example 0,25 years. A linear interpolation will be used in order to determine the stress levels for the different maturities. This can be seen in the table below.

Time to maturity	PC1	PC2	PC3
0	1	1	1
0,246575	1	$1+\frac{0{,}8-1}{0{,}25-0}\cdot(0{,}246575-0)=0{,}80274$	$1+\frac{0{,}64-1}{0{,}25-0}\cdot(0{,}246575-0)=0{,}64493$
0,25	1	0,8	0,64
0,49589	1	$0{,}8+\frac{0{,}6-0{,}8}{0{,}5-0{,}25}\cdot(0{,}49589-0{,}25)=0{,}60329$	$0{,}64+\frac{0{,}27-0{,}64}{0{,}5-0{,}25}\cdot(0{,}49589-0{,}25)=0{,}27608$
0,5	1	0,6	0,27

The table below shows the stressed Swap spot rates when the three principal components are stressed.

Time to maturity	Spot rate	Stressed spot rate
0,246575	2,4676%	$2{,}4676\% + 0{,}22\% \cdot 1 + 0{,}08\% \cdot 080274 - 0{,}05\% \cdot 0{,}64493 = 2{,}720\%$
0,49589	2,4691%	$2{,}4691\% + 0{,}22\% \cdot 1 + 0{,}08\% \cdot 0{,}60329 - 0{,}05\% \cdot 0{,}27608 = 2{,}724\%$

The table below shows the stressed Swap forward-forward rates when the three principal components are stressed.

m	i(0,m)	f(0,m-1,m)	$r_{m-1,m}$
0,246575	2,720%		
0,49589	2,724%	2,728%	2,693%

Equation (26) is used to decide the stressed floating cash flow.

$$\boldsymbol{PnL}_{\text{3MSTIBZ1}}\left(\boldsymbol{r_{m,m+1}}, \boldsymbol{r_c}\right)$$

$$= \mathbf{1} \cdot \mathbf{100} \cdot \mathbf{1\ 000\ 000} \cdot (2{,}441\% - 2{,}693\%) \cdot \frac{90}{\mathbf{360}} = -63\ 000$$

Margin requirement = SEK -63 000.

EXAMPLE 9

BOND FORWARD (NON SYNTHETIC)

POSITIONS

Consider the below portfolio of 100 bought NBHYP2 (2-year Nordbanken Hypotek Bond) contracts.

t	=	2011-02-15
n	=	3
N	=	SEK 1 000 000
C	=	4,25.
Q	=	100
r	=	3,50%
r_t	=	3,55%
d		93
d_e	=	2011-03-10
d_{sett}	=	2011-03-16
C_i	=	

Payment	42 500	42 500	1 042 500
Date	2011-06-19	2012-06-19	2013-06-19

CASH FLOW TABLE

Equation (27) is used to calculate the trade price. It is 93 days between 2011-03-16 and 2011-06-19 in a 30E convention.

$$P_{bond}(3{,}50\%) = 1000\ 000 \cdot \frac{\left(\frac{4{,}25\%}{3{,}50\%} \cdot \left((1+3{,}50\%)^3 - 1\right) + 1\right)}{\left((1+3{,}50\%)^{\left(\frac{93}{360}+3-1\right)}\right)} = 1\ 047\ 398$$

This results in the following cash flow table.

Value date	SEK
2011-03-16	-100 · 1 047 398 = -104 739 800
2011-06-19	100 · 42 500 = 4 250 000
2012-06-19	100 · 42 500 = 4 250 000
2013-06-19	100 · (42 500 + 1000 000) = 104 250 000

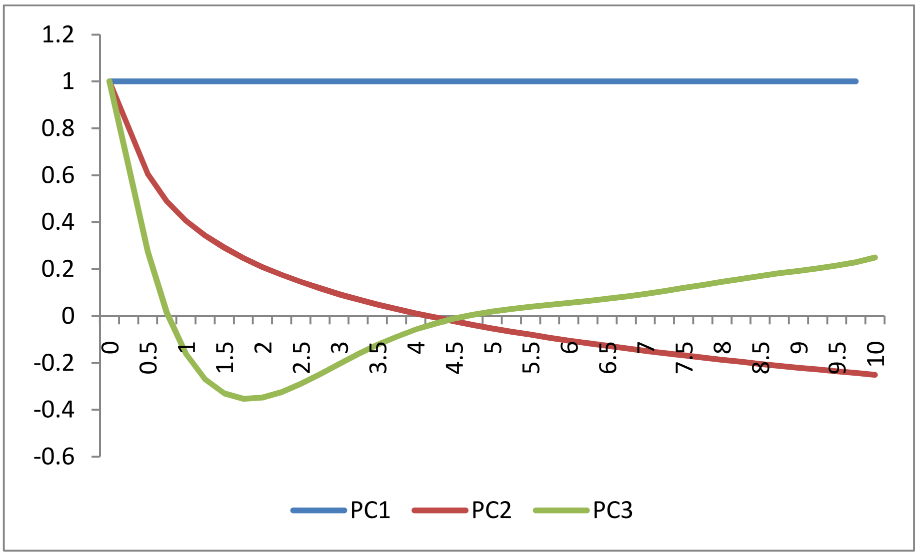
Curve stressing

This position is exposed to a shift in the SEK NBHYP spot curve and it is this curve that will be stressed in the margin calculation.

Risk parameters

The shape of the SEK NBHYP curve's principal components is shown in the figure below.

Figure: Shape of the SEK NBHYP curve's principal components.



The tables below list the stress levels together with the first points of the principal components for the SEK NBHYP curve.

Stress levels

Curve	PC1	PC2	PC3
NBHYP	25 basis points	15 basis points	10 basis points

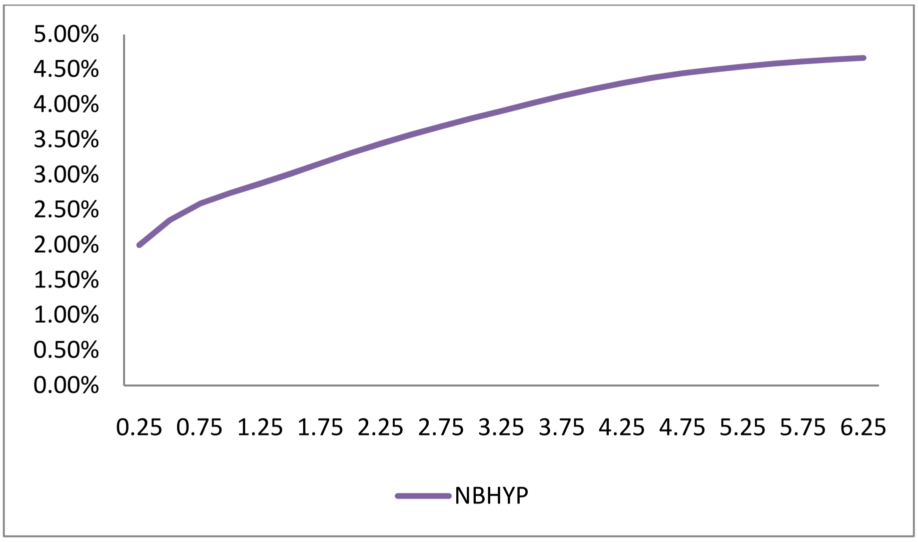
Principal components

Time to maturity	PC1	PC2	PC3
0	1	1	1
0,25	1	0,8	0,64
0,5	1	0,6	0,27
0,75	1	0,49	0,02
1	1	0,41	-0,16
1,25	1	0,34	-0,27
1,5	1	0,29	-0,33
1,75	1	0,25	-0,35
2	1	0,21	-0,35
2,25	1	0,18	-0,32
2,5	1	0,15	-0,29

Official curves

NOMX will, on each trading day, bootstrap official yield curves that will be used to price all cleared instruments. It is the official yield curves that will be stressed in the margin calculations. The underlying bond is issued by Nordbanken Hypotek which means that it will be Nordbanken Hypotek´s official yield curve (NBHYP) that will be used in the margin calculations. In this example it is assumed that the official NBHYP curve looks as in the figure below.

Figure: NBHYP curve



The table below lists the official NBHYP spot rates for the time to maturities that are relevant to the cash flows.

Time to maturity	Spot rate
0,07945	1,501%
0,34247	2,039%
1,34247	2,924%
2,34247	3,493%

Stressed curves

The first cash flow is a negative one and thus the worst scenario for that cash flow will be that all short NBHYP spot rates goes down. However, the position’s cash flows that are most distance are the ones that are derived from the underlying bond. These are all positive cash flows and hence these positions are mainly exposed to an upward shift in the NBHYP curve. If one considers all cash flows, the worst outcome will be the scenario where the first two principal components are stressed upwards and the third principal component is stressed downwards.

Figure: The worst scenario is when the NBHYP curve is stressed upward.

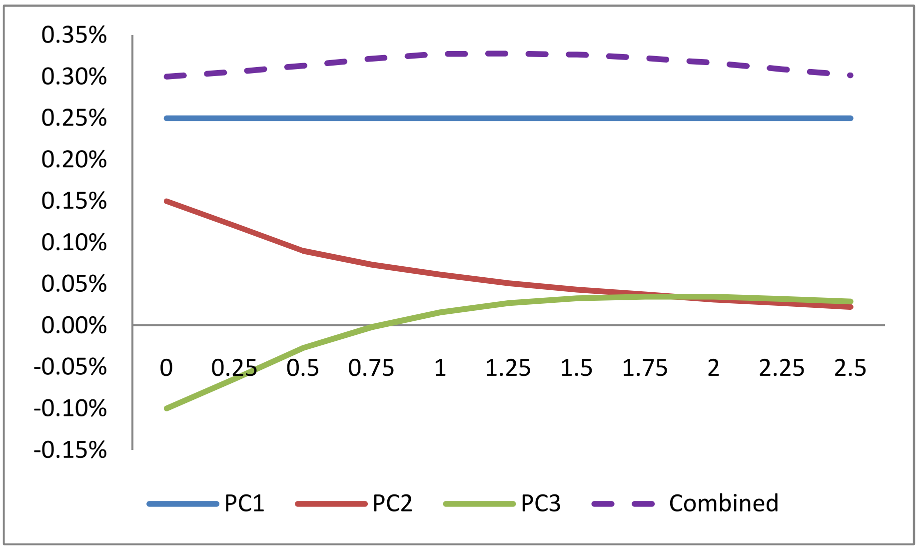
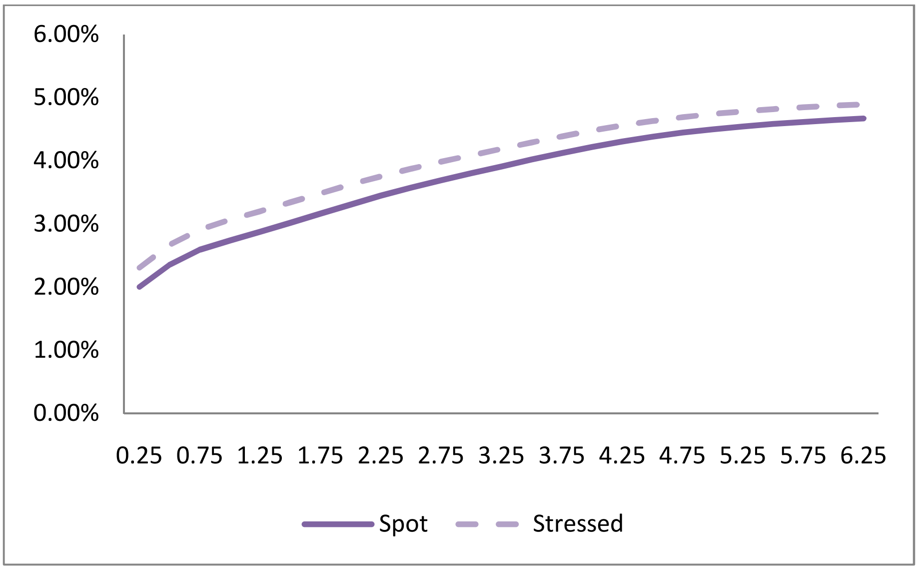


Figure: Official NBHYP curve and stressed NBHYP curve



NOMX defines the principal components in a predefined number of nodes. The distance between each node is in this example 0,25 years. A linear interpolation will be used in order to determine the stress levels for the different maturities. This can be seen in the table below.

Time to maturity	PC1	PC2	PC3
0	1	1	1
0,07945	1	$1+\frac{0{,}8-1}{0{,}25-0}\cdot(0{,}07945-0) = 0{,}93644$	$1+\frac{0{,}64-1}{0{,}25-0}\cdot(0{,}07945-0) = 0{,}88559$
0,25	1	0,8	0,64
0,33973	1	$0{,}8+\frac{0{,}6-0{,}8}{0{,}5-0{,}25}\cdot(0{,}33973-0{,}25) = 0{,}72822$	$0{,}64+\frac{0{,}27-0{,}64}{0{,}5-0{,}25}\cdot(0{,}33973-0{,}25) = 0{,}50720$
0,5	1	0,6	0,27

0,75	1	0,49	0,02
1	1	0,41	-0,16
1,25	1	0,34	-0,27
1,34247	1	$0{,}34+\frac{0{,}29-0{,}34}{1{,}5-1{,}25}\cdot(1{,}34247-1{,}25)=0{,}32151$	$-0{,}27+\frac{-0{,}33+0{,}27}{1{,}5-1{,}25}\cdot(1{,}34247-1{,}25)=-0{,}29219$
1,5	1	0,29	-0,33
1,75	1	0,25	-0,35
2	1	0,21	-0,35
2,25	1	0,18	-0,32
2,34247		$0{,}18+\frac{0{,}15-0{,}18}{2{,}5-2{,}25}\cdot(2{,}34247-2{,}25)=0{,}16890$	$-0{,}32+\frac{-0{,}29+0{,}32}{2{,}5-2{,}25}\cdot(2{,}34247-2{,}25)=-0{,}30890$
2,5	1	0,15	-0,29

The table below shows the stressed NBHYP spot rates when the three principal components are stressed.

Time to maturity	Spot rate	Stressed spot rate
0,07945	1,501%	$1{,}501\%+0{,}25\%\cdot 1+0{,}15\%\cdot 0{,}93644-0{,}10\%\cdot 0{,}88559=1{,}803\%$
0,33973	2,039%	$2{,}039\%+0{,}25\%\cdot 1+0{,}15\%\cdot 0{,}72822-0{,}10\%\cdot 0{,}50720=2{,}347\%$
1,34247	2,924%	$2{,}924\%+0{,}25\%\cdot 1+0{,}15\%\cdot 0{,}32151+0{,}10\%\cdot 0{,}29219=3{,}251\%$
2,34247	3,493%	$3{,}493\%+0{,}25\%\cdot 1+0{,}15\%\cdot 0{,}16890+0{,}10\%\cdot 0{,}30890=3{,}799\%$

Net present value

The margin requirement is obtained by calculating the net present value of the cash flows in the cash flow table.

In this example all cash flows are in SEK and are exposed to the NBHYP curve. It should be noted that the NPV is calculated from a yield curve built up by bonds from the issuer. The bond forward itself is not a calibration instrument and thus the unstressed NPV will slightly deviate from the market value. However, when NOMX presents the market value in e.g. margin reports the instrument will get its market value from the margin price in the Price Server i.e. the market value will be calculated from equation (19) and based on the difference between the traded price (r) and today's fixed price (r_t). If, on the other hand, the net present value is calculated with the stressed SEK NBHYP curve, then the bond forward position's margin requirement is obtained.

Value date	Time to maturity	SEK
2011-03-16	0,07945	-104 739 800
2011-06-19	0,33973	4 250 000
2012-06-19	1,34247	4 250 000
2013-06-19	2,34247	104 250 000
Market value		$100 * [\mathrm{P_{bond}}(3{,}55\%) - \mathrm{P_{bond}}(3{,}50\%)] = -108\,200$
NPV stressed		$\frac{-104\,739\,800}{(1+1{,}803\%)^{0{,}07945}} + \cdots + \frac{104\,250\,000}{(1+3{,}799\%)^{2{,}34247}} = -772\,533$

Market value = SEK -108 200

Margin requirement = SEK -772 533

Example 10

Bond forward (synthetic)

Consider the below portfolio of 100 sold R2RR (government bond) contracts. The forward contract is traded on the forward yield of the deliverable bond and thus the bond forward will be valued by using the forward yield to maturity of the deliverable bond as implied by the yield curve. The P/L is however calculated using the characteristics of the synthetic bond. Using CFM to calculate margin for these contracts therefore requires some additional steps compared to the usual cash flow discounting used for most other interest rate derivatives. In short, the cash flows of the synthetic bond forward will be forward valued, not by using the yield curve, but by using the forward yield to maturity of the deliverable bond as implied by the yield curve. The deliverable bond for R2RR is RGKB1041 with maturity 2014-05-05 and a coupon rate of 6,75%.

t = 2011-03-02
n = 3
N = SEK 1 000 000
C = 6,75.
Q = -100
r = 2,99%
r_t = 2,99%
d = 320
d_e = 2011-06-09
d_{sett} = 2011-06-15
d_c = 2012-05-05
C_i =

Payment	67 500	67 500	1 067 500
Date	2012-05-05	2013-05-05	2014-05-05

Equation (27) is used to calculate the trade price. It is 320 days between 2011-06-15 and 2012-05-05 in a 30E convention.

$$P_{bond}(2{,}99\%) = 1000\ 000 \cdot \frac{\left(\frac{6{,}75\%}{2{,}99\%} \cdot ((1+2{,}99\%)^3 - 1) + 1\right)}{\left((1+2{,}99\%)^{\left(\frac{320}{360}+3-1\right)}\right)} = 1\ 110\ 004$$

This would result in the following cash flow table.

Value date	SEK
2011-06-15	100 · 1 110 004 = 111 000 400
2012-05-05	-100 · 67 500 = -6 750 000
2013-05-05	-100 · 67 500 = -6 750 000
2014-05-05	-100 · (67 500 + 1000 000) = -106 750 000

The forward-forward rate $f(0, m, m_i)$ will be derived from the treasury curve. The forward-forward rates and the above cash flows are inserted into Equation (20) to calculate the forward price quoted in yield of the deliverable bond. Equation (19) will then be used to determine a forward price in money of the synthetic bond forward.

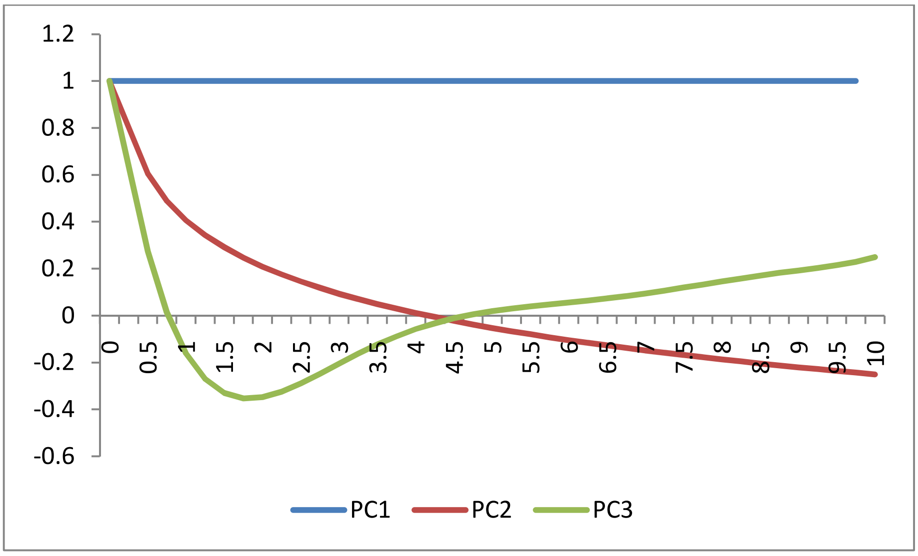
Curve stressing

This position is exposed to a shift in the SEK treasury spot curve and it is this curve that will be stressed in the margin calculation.

Risk parameters

The shape of the SEK treasury curve's principal components is shown in the figure below.

Figure: Shape of the SEK treasury curve's principal components.



The tables below list the stress levels together with the first points of the principal components for the SEK treasury curve.

Stress levels

Curve	PC1	PC2	PC3
NBHYP	22 basis points	8 basis points	5 basis points

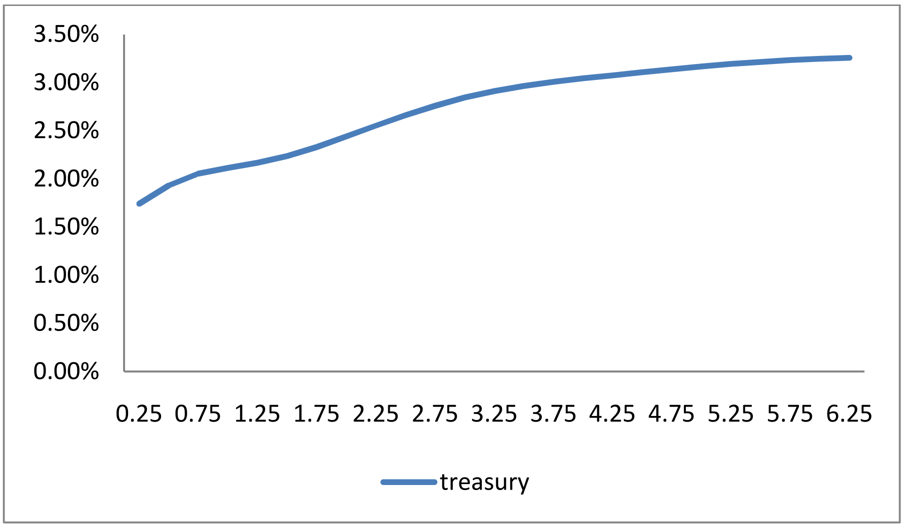
Principal components

Time to maturity	PC1	PC2	PC3
0	1	1	1
0,25	1	0,8	0,64
0,5	1	0,6	0,27
0,75	1	0,49	0,02
1	1	0,41	-0,16
1,25	1	0,34	-0,27
1,5	1	0,29	-0,33
1,75	1	0,25	-0,35
2	1	0,21	-0,35
2,25	1	0,18	-0,32
2,5	1	0,15	-0,29
2,75	1	0,12	-0,25
3	1	0,09	-0,21

3,25	1	0,07	-0,16
3,5	1	0,05	-0,12

OFFICIAL CURVES

NOMX will, on each trading day, bootstrap official yield curves that will be used to price all cleared instruments. It is the official yield curves that will be stressed in the margin calculations. In this example it is assumed that the official SEK treasury spot curve look as in the figure below.



The table below lists the official swap spot and forward-forward rates for the maturities that are relevant to the cash flows in the treasury cash flow table. Equation (2) has been used to calculate the forward-forward rates, $f(0, m_t, m_T)$, from the spot rates, $i(0, m)$.

m	i(0,m)	f(0,m,m+i)
0,28767	1,757%	
1,17808	2,162%	$\left(\frac{(1+2{,}162\%)^{1{,}17808}}{(1+1{,}757\%)^{0{,}28767}}\right)^{\frac{1}{(1{,}17808-0{,}28767)}} - 1 = 2{,}293\%$
2,17808	2,523%	$\left(\frac{(1+2{,}523\%)^{2{,}17808}}{(1+1{,}757\%)^{0{,}28767}}\right)^{\frac{1}{(2{,}17808-0{,}28767)}} - 1 = 2{,}640\%$
3,17808	2,894%	$\left(\frac{(1+2{,}894\%)^{3{,}17808}}{(1+1{,}757\%)^{0{,}28767}}\right)^{\frac{1}{(3{,}17808-0{,}28767)}} - 1 = 3{,}007\%$

The next step is to calculate a forward price quoted in yield for the deliverable bond. The forward yield to maturity, y, is the solution of Equation(20). Note that the time in this equation relates to the time between the expiration date of the forward and the cash flow date.

$$\frac{6\ 750\ 000}{(1+2{,}293\%)^{320/360}} + \frac{6\ 750\ 000}{(1+2{,}640\%)^{680/360}} + \frac{106\ 750\ 000}{(1+3{,}007\%)^{1040/360}} = \frac{6\ 750\ 000}{(1+y)^{320/360}} + \frac{6\ 750\ 000}{(1+y)^{680/360}} + \frac{106\ 750\ 000}{(1+y)^{1040/360}} => y = 2{,}979\%$$

Equation (19) will be used to convert the yield into a price for the synthetic bond.

$$P_{bond}(2{,}979\%) = 1000\ 000 \cdot \frac{\left(\frac{6\%}{2{,}979\%} \cdot ((1+2{,}979\%)^2 - 1) + 1\right)}{\left((1+2{,}979\%)^{\left(\frac{360}{360}+2-1\right)}\right)} = 1\ 057\ 824$$

STRESSED CURVES

The first cash flow is a positive one and thus the worst scenario for that cash flow will be that all short treasury spot rates goes up. However, the position's cash flows that are most distance are the ones that are derived from the underlying bond. These are all negative cash flows and hence these positions are mainly exposed to a downward shift in the treasury curve. If one considers all cash flows, the worst outcome will be the scenario where the first two principal components are stressed downwards and the third principal component is stressed upwards.

Figure: The worst scenario is when the treasury curve is stressed downward

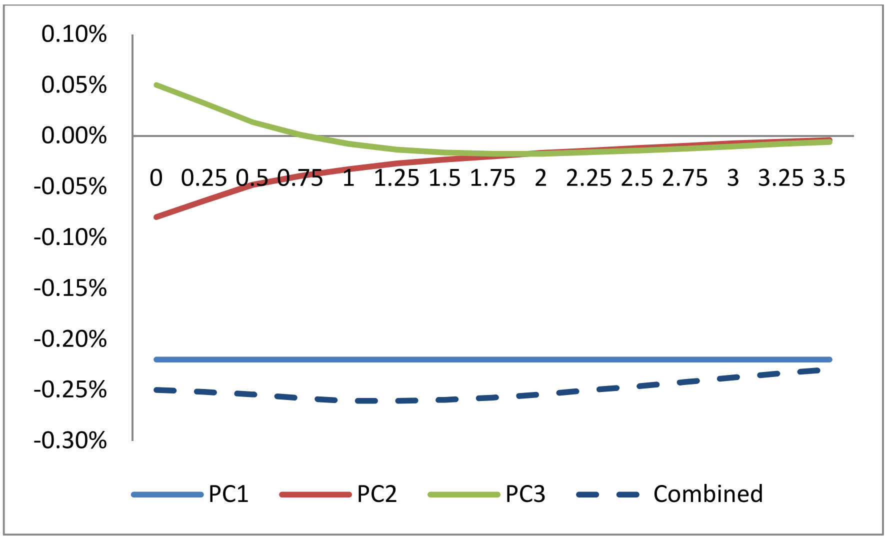
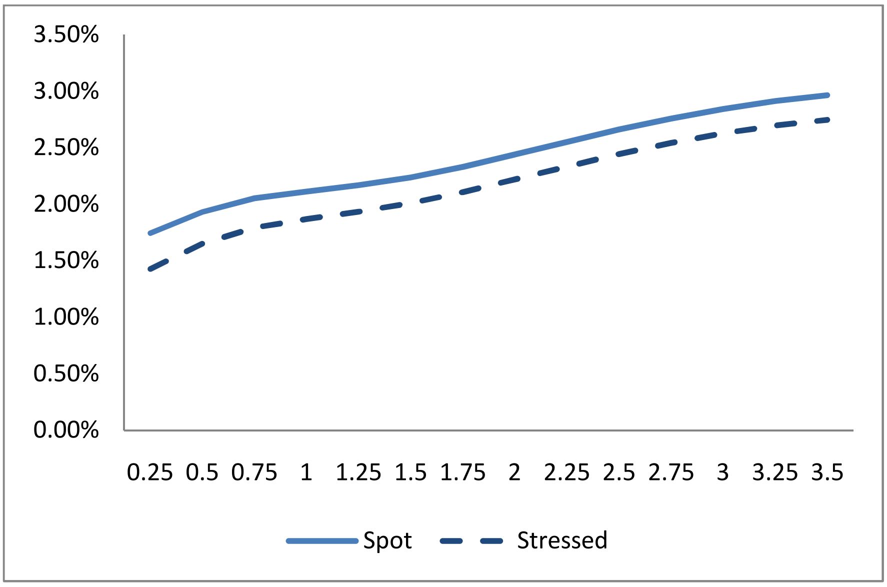


Figure: Official treasury curve and stressed treasury curve



NOMX defines the principal components in a predefined number of nodes. The distance between each node is in this example 0,25 years. A linear interpolation will be used in order to determine the stress levels for the different maturities. This can be seen in the table below.

Time to maturity	PC1	PC2	PC3
0	1	1	1
0,25	1	0,8	0,64
0,28767	1	$0{,}8+\frac{0{,}6-0{,}8}{0{,}5-0{,}25}\cdot(0{,}28767-0{,}25)=0{,}76986$	$0{,}64+\frac{0{,}27-0{,}64}{0{,}5-0{,}25}\cdot(0{,}28767-0{,}25)=0{,}58425$
0,5	1	0,6	0,27
0,75	1	0,49	0,02
1	1	0,41	-0,16
1,17808	1	$0{,}41+\frac{0{,}34-0{,}41}{1{,}25-1}\cdot(1{,}17808-1)=0{,}36014$	$-0{,}16+\frac{-0{,}27+0{,}16}{1{,}25-1}\cdot(1{,}17808-1)=-0{,}23836$
1,25	1	0,34	-0,27
1,5	1	0,29	-0,33
1,75	1	0,25	-0,35
2	1	0,21	-0,35
2,17808	1	$0{,}21+\frac{0{,}18-0{,}21}{2{,}25-2}\cdot(2{,}17808-2)=0{,}18863$	$-0{,}35+\frac{-0{,}32+0{,}35}{2{,}25-2}\cdot(2{,}17808-2)=-0{,}32863$
2,25	1	0,18	-0,32
2,5	1	0,15	-0,29
2,75	1	0,12	-0,25
3	1	0,09	-0,21
3,17808	1	$0{,}09+\frac{0{,}07-0{,}09}{3{,}25-3}\cdot(3{,}17808-3)=0{,}07575$	$-0{,}21+\frac{-0{,}16+0{,}21}{3{,}25-3}\cdot(3{,}17808-3)=-0{,}17438$
3,25	1	0,07	-0,16
3,5	1	0,05	-0,12

After the SEK treasury spot rates have been stressed then Equation (2) is used to update the SEK treasury forward-forward rates. The tables below list the official and the stressed SEK treasury rates.

m	i(0,m)	i(0,m) (stressed)
0,28767	1,757%	$1{,}757\% - 0{,}22\% \cdot 1 - 0{,}08\% \cdot 76986 + 0{,}05\% \cdot 0{,}58425 = 1{,}505\%$
1,17808	2,162%	$2{,}162\% - 0{,}22\% \cdot 1 - 0{,}08\% \cdot 0{,}36014 - 0{,}05\% \cdot 0{,}23836 = 1{,}901\%$
2,17808	2,523%	$2{,}523\% - 0{,}22\% \cdot 1 - 0{,}08\% \cdot 0{,}18863 - 0{,}05\% \cdot 0{,}32863 = 2{,}271\%$
3,17808	2,894%	$2{,}894\% - 0{,}22\% \cdot 1 - 0{,}08\% \cdot 0{,}07575 - 0{,}05\% \cdot 0{,}17438 = 2{,}659\%$

m	i(0,m) (stressed)	f(0,m,m+i) (stressed)
0,28767	1,505%	
1,17808	1,901%	$\left(\frac{(1+1{,}901\%)^{1{,}17808}}{(1+1{,}505\%)^{0{,}28767}}\right)^{\frac{1}{(1{,}17808-0{,}28767)}} - 1 = 2{,}030\%$
2,17808	2,271%	$\left(\frac{(1+2{,}271\%)^{2{,}17808}}{(1+1{,}505\%)^{0{,}28767}}\right)^{\frac{1}{(2{,}17808-0{,}28767)}} - 1 = 2{,}389\%$
3,17808	2,659%	$\left(\frac{(1+2{,}659\%)^{3{,}17808}}{(1+1{,}505\%)^{0{,}28767}}\right)^{\frac{1}{(3{,}17808-0{,}28767)}} - 1 = 2{,}775\%$

STRESSED NET PRESENT VALUE

Equation (28) is used to calculate a forward price quoted in yield for the deliverable bond with the stressed forward-forward rates. The forward yield to maturity, y_{stress}, is the solution of Equation (28). Note that the time in this equation relates to the time between the expiration date of the forward and the cash flow date.

$$\frac{6\ 750\ 000}{(1+2{,}030\%)^{320/360}} + \frac{6\ 750\ 000}{(1+2{,}389\%)^{680/360}} + \frac{106\ 750\ 000}{(1+2{,}775\%)^{1040/360}} = \frac{6\ 750\ 000}{(1+y_{\mathrm{stress}})^{320/360}} + \frac{6\ 750\ 000}{(1+y_{\mathrm{stress}})^{680/360}} + \frac{106\ 750\ 000}{(1+y_{\mathrm{stress}})^{1040/360}} => y_{\mathrm{stress}} = 2{,}745\%$$

Equation (27) will be used to convert the stressed yield into a stressed price for the synthetic bond.

$$P_{bond}(2{,}745\%) = 1000\ 000 \cdot \frac{\left(\frac{6\%}{2{,}745\%} \cdot \left((1+2{,}745\%)^2 - 1\right) + 1\right)}{\left((1+2{,}745\%)^{\left(\frac{360}{360}+2-1\right)}\right)} = 1\ 062\ 514$$

The margin requirement is obtained by comparing the stressed price from the stressed curve with the price obtained by the unstressed curve. Note that this is forward prices which have to be discounted back to today i.e. 2011-03-02 to get a stressed net present value.

The market value will be calculated from equation (27) and is based on the difference between the traded price (r) and today's fixed price (r_t). In this example it is assumed that the traded price and the fixed price are equal. If, on the other hand, the net present value is calculated with the stressed SEK treasury curve, then the bond forward position's margin requirement is obtained.

Market value	$\mathbf{P_{bond}(2,99\%) - P_{bond}(2,99\%) = 0}$
NPV stressed	$\frac{105\ 782\ 400}{(1+1{,}505\%)^{0{,}28767}} - \frac{106\ 251\ 400}{(1+1{,}505\%)^{0{,}28767}} = -466\ 989$

Market value = SEK 0

Margin requirement = SEK -466 989

APPENDICES

APPENDIX I

BOOTSTRAPPING YIELD CURVES USING CUBIC SPLINES

NOMX applies a cubic spline bootstrapping methodology to obtain the yield curves. This appendix describes the cubic spline bootstrapping methodology.

OBJECTIVE

The objective is to find a discount function, $d(0,m)$, that prices all calibration instruments correct and that is smooth and has a smooth first and second derivative.

BASIC ASSUMPTIONS

The discount function is divided in a number of nodes, and it is assumed that it can be expressed as a 3rd degree polynomial in between these nodes. This implies that the discount function can be written as Equation (31).

$$\boldsymbol{d(0,m) = a_{i,i+1} + b_{i,i+1} \cdot (m - m_i) + c_{i,i+1} \cdot (m - m_i)^2 + d_{i,i+1} \cdot (m - m_i)^3} \qquad \mathbf{31}$$

PROBLEM

The problem is to find the coefficients $a_{i,j}$, $b_{i,j}$, $c_{i,j}$, $d_{i,j}$. If these are found then the discount function is defined on the interval $[0, m_{end}]$. The discount function is divided in x nodes, were x is the number of calibration instruments. Each node lay at the end date of the calibration instrument's underlying rate period. Equation (31) gives four unknown coefficients per node interval, and this results in a total of 4 · x unknown coefficients.

SOLUTION

PRICE EQUATIONS

The discount function must price all calibration instruments correct. The x number of calibration instruments therefore give x price equations. The price equation will look different depending on which type of instrument that is used as calibration instrument.

BILLS

Equation (32) can be used to relate the discount function to the price of a bill.

$$\boldsymbol{d(0,m_{exp}) = \frac{1}{1 + r_b \cdot \frac{n_{t+2,x}}{360}} \cdot d(0,m_{t+2})} \qquad \mathbf{32}$$

$n_{t+2,x}$ is the actual number of days between t+2 and x, and r_b is the bill's yield.

BONDS

Equation (33) can be used to relate the discount function to the dirty price of a bond.

$$d(0, m_{t+3}) \cdot P_{bond} = \sum_i (C_i \cdot d(0, m_i)) + (100 + C_{last}) \cdot d(0, m_{last}) \qquad 33$$

C_i is the coupon payment at time T_i.

Deposits

Equation (34) can be used to relate the discount function to the price of a deposit.

$$d(0, m_{exp}) = \frac{1}{1 + r_d \cdot \frac{n_{t+2,x}}{360}} \cdot d(0, m_{t+2}) \qquad 34$$

$n_{t+2,x}$ is the actual number of days between t+2 and x, and r_d is the deposit rate.

Forward rate agreements

Equation (35) can be used to relate the discount function to the price of a FRA contract.

$$d(0, m_s) \cdot \frac{1}{1 + r_{FRA} \cdot \frac{n_{s,e}}{360}} = d(0, m_e) \qquad 35$$

r_{FRA} is the FRA rate, $n_{s,e}$ is the actual number of days between the start and the end date of the FRA contract's underlying rate period.

Other derivates on forward starting deposits, such as RIBA futures, CIBOR futures and STIBOR futures, also will use this price equation when used in curve generation. Note that for the first RIBA future, the implicit rate is derived through adjusting for the already known repo rate fixing, as described above.

Interest rate swaps

Equation (36) can be used to relate the price of an interest rate swap to the discount function.

$$d(0, m_{t+2}) \cdot N = \sum_i r_f \cdot \frac{n_{i-1,i}}{360} \cdot N \cdot d(0, m_i) + (1 + r_f \cdot \frac{n_{last-1,last}}{360}) \cdot N \cdot d(0, m_{last}) \qquad 36$$

N is the principal amount, r_f is the fixed rate of the interest rate swap, and $n_{i-1,i}$ is the number of days between date i-1 and i (measured as 30E).

Geometrical equations

Except for the price equations there are also geometrical constrictions to the discount function. It is required $d(0, m)$, $d'(0, m)$ and $d''(0, m)$ are continuous at all nodes. This implies the following relationships (which results in 3x-3 geometrical equations).

Discount function must be continuous

$$a_{i,i+1} + b_{i,i+1} \cdot (m_{i+1} - m_i) + c_{i,i+1} \cdot (m_{i+1} - m_i)^2 + d_{i,i+1} \cdot (m_{i+1} - m_i)^3 - a_{i+1,i+2} = 0 \qquad 37$$

Discount function must have a continuous derivative

$$b_{i,i+1} + 2 \cdot c_{i,i+1} \cdot (m_{i+1} - m_i) + 3 \cdot d_{i,i+1} \cdot (m_{i+1} - m_i)^2 - b_{i+1,i+2} = 0 \quad 38$$

Discount function must have a continuous second derivative

$$2 \cdot c_{i,i+1} + 6 \cdot d_{i,i+1}(m_{i+1} - m_i) - 2 \cdot c_{i+1,i+2} = 0 \quad 39$$

Boundary conditions

The following three boundary conditions are applied.

- The discount function is defined to start at 1 i.e. $d(0,0) = 1$.

  $$a_{0,1} = 1 \quad 40$$

- The discount function is assumed to have a smooth start i.e. $d''(0,0) = 1$.

  $$c_{0,1} = 0 \quad 41$$

- The discount function is assumed to reach an equilibrium state i.e. $d''(0, m_{end}) = 0$.

  $$2 \cdot c_{end-1,end} + 6 \cdot d_{end-1,end}(m_{end} - m_{end-1}) = 0 \quad 42$$

System of linear equations

The price equations, geometrical equations and boundary conditions result in a total of 4 · x equations. These can be solved for all unknown coefficients $a_{i,j}$, $b_{i,j}$, $c_{i,j}$, $d_{i,j}$. When the coefficients have been found then Equation (31) can be used to calculate the discount function for any time to maturity on the interval $[0, m_{end}]$.

Appendix II

Principal components analysis

NOMX will stress each yield curve with its first three principal components. The principal component analysis will be performed outside of the GENIUM INET system and the principal components together with their stress levels will be entered into GENIUM INET as risk parameters. This appendix describes the principal component analysis.

Objective

The objective is to find independent (uncorrelated) moves of a yield curve; these will later be used to simulate changes to the yield curve.

Input data

NOMX defines the yield curves as interest rate values at different times to maturities (nodes).

Time to maturity	m_0	…	m_i	…	m_{end}
Spot rate	$i(t,m_0)$	…	$i(t,m_i)$	…	$i(t,m_{end})$

The input data to the principal components analysis is a time series of historical changes to these node values.

Date	m_0	…	m_{end}
t_i	$\lvert i(t_i,m_0)-i(t_{i-1},m_0)\rvert$	…	$\lvert i(t_i,m_{end})-i(t_{i-1},m_{end})\rvert$
t_{i-1}	$\lvert i(t_{i-1},m_0)-i(t_{i-2},m_0)\rvert$	…	$\lvert i(t_{i-1},m_{end})-i(t_{i-2},m_{end})\rvert$
…	…	…	…
t_{i-500}	$\lvert i(t_{i-500},m_0)-i(t_{i-501},m_0)\rvert$	…	$\lvert i(t_{i-500},m_{end})-i(t_{i-501},m_{end})\rvert$

Definitions

Covariance matrix

The covariance matrix contains information on each node's historical variance as well as the covariance between the different nodes. The covariance matrix is defined accordingly.

$$\boldsymbol{COV(i,j)} = \frac{\sum(x_i-\bar{x}_i)(x_j-\bar{x}_j)}{\boldsymbol{n}} \qquad 43$$

x_i is the daily change of node i, x_j is the daily change of node j, and n is the total number of observations.

When performing the principal components analysis it is important that the input data is arranged so that the means $\bar{x}_i$ and $\bar{x}_j$ are zero[5]. If this is not correct then the means must be removed from the time series before the analysis proceeds.

[5] Please see Jolliffe, I.T. *Principal Components Analysis, 2nd edition*, Springer series in statistics

Principal components

The principal components are defined as the eigenvectors, λ, to the covariance matrix.

$$\overleftrightarrow{COV} \cdot \bar{\lambda} = \sigma \cdot \bar{\lambda} \quad (44)$$

The eigenvectors are orthogonal i.e. independent (uncorrelated). An eigenvector's eigenvalue, σ, reveals how much of the curve's total variance that is explained by this eigenvector. It should be noted that this definition implies that the principal components are in fact lists of changes to the interest rate values at the nodes.

Time to maturity	m_0	…	m_i	…	m_{end}
Spot rate change	1	…	0,9	…	0,4

Problem

The first problem is to find the eigenvalues, σ, to the covariance matrix. This is done by solving Equation (35). *I* in Equation (35) stands for the identification matrix.

$$\det\left(\overleftrightarrow{COV} - \sigma \cdot \overleftrightarrow{I}\right) = 0 \quad (45)$$

When the eigenvalues are found, then each of them can be inserted into Equation (44), resulting in a system of linear equations that can be solved for their corresponding eigenvectors, λ.

Solution

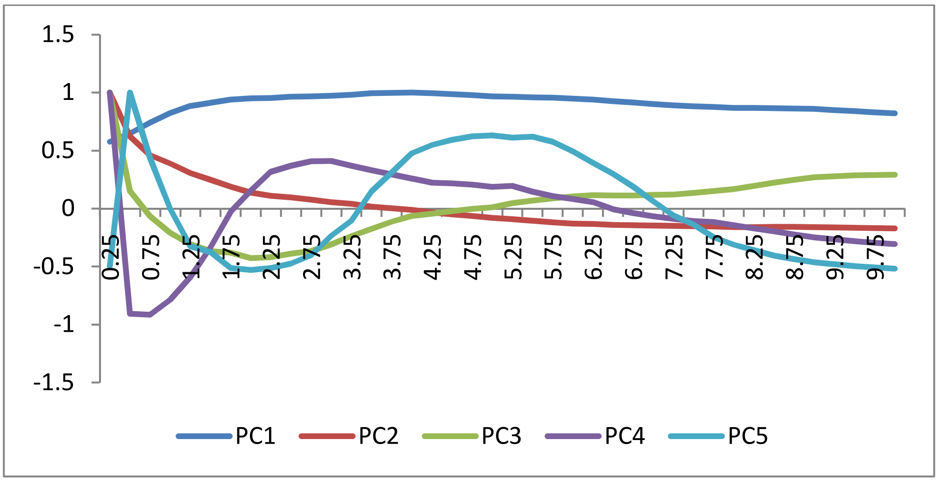
If the yield curve is defined on x nodes, then the covariance matrix will have size $x \cdot x$. Equation (45) will then result in x eigenvalues (assuming no doublets) and hence also x eigenvectors/principal components.

If the size of all eigenvalues is compared, then it is possible to determine the importance of each principal component. The table below shows the relative importance of the SEK swap curve's first seven principal components.

Principal component	PC1	PC2	PC3	PC4	PC5	PC6	PC7
Explanation factor	76,5%	12,7%	5,1%	2,0%	0,9%	0,7%	0,4%

The Risk parameters are dependent on the principal components. From the principal components analysis the eigenvectors are by definition orthonormal i.e. orthogonal vectors with magnitude 1. NASDAQ OMX has chosen to scale the eigenvectors/principal components and that will affect both the magnitude of the eigenvector and the risk parameter i.e. the greater the magnitude the lower the risk parameter. However, the direction of the eigenvector will not change which means that the actual stress (Risk parameter * $\overline{PC}$) will not change depending of the magnitude of the principal components

Figure: First five scaled principal components of the SEK swap curve.



Appendix III

One-dimensional window method

This appendix gives an example on the one-dimensional window method. The example is fictive (the one dimensional window method will never be applied in NOMX CFM), but reading the example will hopefully facilitate the understanding of the multi-dimensional window methods used in NOMX CFM.

Positions

The position in this example is a EURUSD basis swap. For a given set of yield curves the stressed net present value is given in the cash flow table below.

Value date	USD	EUR
...	...	...
NPV stressed	1 000 000	-667 315

These stressed net present values must be converted into the margin base currency (SEK). If the USDSEK or EURSEK spot exchange rates changes, then the converted value will also change. This risk is accounted for by stressing the spot exchange rates.

Margin data

The margin data is given in the table below.

Currency pair	Spot rate	Risk parameter
USDSEK	6,86	4%
EURSEK	10,28	3%

Scanning range intervals

NOMX stresses the spot exchange rates upwards and downwards with the appropriate risk parameters. This results in the following two scanning range intervals.

USDSEK

$$[\,6{,}86 \cdot (1 - 0{,}04), 6{,}86 \cdot (1 + 0{,}04)\,] = [\,6{,}59, 7{,}13\,]$$

EURSEK

$$[\,10{,}28 \cdot (1 - 0{,}03), 10{,}28 \cdot (1 + 0{,}03)\,] = [\,9{,}97, 10{,}59\,]$$

Vector files

NOMX produces a USD and a EUR vector file. The vector files contain 31 nodes and the USDSEK and EURSEK spot exchange rates will be varied, evenly distributed over their scanning range intervals, in these nodes. Every node further contains the stressed net present value converted into SEK using the node’s spot exchange rate.

Window class

In this example it is supposed that the USDSEK and EURSEK currency pairs are in the same window class and that this window class has a window size of 11 nodes.

ONE-DIMENSIONAL WINDOW METHOD

The one-dimensional window method starts by listing the USD and EUR vector files next to each other and by creating a "USD, EUR result vector" (refer to the figure below).

WINDOW STARTS IN NODE 1

A window of 11 nodes is then placed in the top node of the vector files. The window represent the maximum amount that the USDSEK and EURSEK spot exchange rates are anticipated to deviate from each other. The value at node 1 of the result vector is the sum of the worst outcomes from the nodes in the USD and EUR vector files that lay inside of the window.

In this example this is node 6 of the USD vector file (i.e. that the USDSEK spot rate goes up to 7,04) and node 1 of the EUR vector file (i.e. that EURSEK spot rate goes up to 10,59). This combined result is entered into node 1 of the result vector.

Figure: A window starts at the top node of the vector files. The value in the result vector is the sum of the worst outcome within the window.

USD vector file			EUR vector file			USD, EUR result vector			
Node	USDSEK	NPV (SEK)	Node	EURSEK	NPV (SEK)	Node	USDSEK	EURSEK	NPV (SEK)
1	7,13	7 134 400	**1**	**10,59**	**-7 065 800**	**1**	**7,04**	**10,59**	**-22 867**
2	7,12	7 116 107	2	10,57	-7 052 080	2			
3	7,10	7 097 813	3	10,55	-7 038 360	3			
4	7,08	7 079 520	4	10,53	-7 024 640	4			
5	7,06	7 061 227	5	10,51	-7 010 920	5			
6	**7,04**	**7 042 933**	6	10,49	-6 997 200	6			
7	7,02	7 024 640	7	10,4[illegible]	-6 983 480	7			
8	7,01	7 006 347	8	10,[illegible]	-6 969 760	8			
9	6,99	6 988 053	9	10,[illegible]	-6 956 040	9			
10	6,97	6 969 760	10	10,[illegible]	-6 942 320	10			
11	6,95	6 951 467	11	10,[illegible]	-6 928 600	11			
12	6,93	6 933 173	12	10,[illegible]	-6 914 880	12			
13	6,91	6 914 880	13	10[illegible]	-6 901 160	13			
14	6,90	6 896 587	14	10,3[illegible]	-6 887 440	14			
15	6,88	6 878 293	15	10,30	-6 873 720	15			
16	6,86	6 860 000	16	10,28	-6 860 000	16			
17	6,84	6 841 707	17	10,26	-6 846 280	17			
18	6,82	6 823 413	18	10,24	-6 832 560	18			
19	6,81	6 805 120	19	10,22	-6 818 840	19			
20	6,79	6 786 827	20	10,20	-6 805 120	20			
21	6,77	6 768 533	21	10,18	-6 791 400	21			
22	6,75	6 750 240	22	10,16	-6 777 680	22			
23	6,73	6 731 947	23	10,14	-6 763 960	23			
24	6,71	6 713 653	24	10,12	-6 750 240	24			
25	6,70	6 695 360	25	10,09	-6 736 520	25			
26	6,68	6 677 067	26	10,07	-6 722 800	26			
27	6,66	6 658 773	27	10,05	-6 709 080	27			
28	6,64	6 640 480	28	10,03	-6 695 360	28			
29	6,62	6 622 187	29	10,01	-6 681 640	29			
30	6,60	6 603 893	30	9,99	-6 667 920	30			
31	6,59	6 585 600	31	9,97	-6 654 200	31			

Window slides down

The window will slide down all 31 nodes of the vector files. The value in the result vector is always the sum of the worst outcomes within the window.

At note 16 this is equal the value from node 21 of the USD vector file (i.e. that the USDSEK spot rate goes down to 6,77) plus the value from node 11 of the EUR vector file (i.e. that the EURSEK spot rate goes up to 10,38).

Figure: The window will slide down all 31 nodes of the vector files.

USD vector file

Node	USDSEK	NPV (SEK)
1	7,13	7 134 400
2	7,12	7 116 107
3	7,10	7 097 813
4	7,08	7 079 520
5	7,06	7 061 227
6	7,04	7 042 933
7	7,02	7 024 640
8	7,01	7 006 347
9	6,99	6 988 053
10	6,97	6 969 760
11	6,95	6 951 467
12	6,93	6 933 173
13	6,91	6 914 880
14	6,90	6 896 587
15	6,88	6 878 293
16	6,86	6 860 000
17	6,84	6 841 707
18	6,82	6 823 413
19	6,81	6 805 120
20	6,79	6 786 827
21	**6,77**	**6 768 533**
22	6,75	6 750 240
23	6,73	6 731 947
24	6,71	6 713 653
25	6,70	6 695 360
26	6,68	6 677 067
27	6,66	6 658 773
28	6,64	6 640 480
29	6,62	6 622 187
30	6,60	6 603 893
31	6,59	6 585 600

EUR vector file

Node	EURSEK	NPV (SEK)
1	10,59	-7 065 800
2	10,57	-7 052 080
3	10,55	-7 038 360
4	10,53	-7 024 640
5	10,51	-7 010 920
6	10,49	-6 997 200
7	10,47	-6 983 480
8	10,44	-6 969 760
9	10,42	-6 956 040
10	10,40	-6 942 320
11	**10,38**	**-6 928 600**
12	10,36	-6 914 880
13	10,34	-6 901 160
14	10,32	-6 887 440
15	10,30	-6 873 720
16	10,28	-6 860 000
17	10,26	-6 846 280
18	10,24	-6 832 560
19	10,22	-6 818 840
20	10,20	-6 805 120
21	10,18	-6 791 400
22	10,16	-6 777 680
23	10,14	-6 763 960
24	10,12	-6 750 240
25	10,09	-6 736 520
26	10,07	-6 722 800
27	10,05	-6 709 080
28	10,03	-6 695 360
29	10,01	-6 681 640
30	9,99	-6 667 920
31	9,97	-6 654 200

USD, EUR result vector

Node	USDSEK	EURSEK	NPV (SEK)
1	7,04	10,59	-22 867
2	7,02	10,59	-41 160
3	7,01	10,59	-59 453
4	6,99	10,59	-77 747
5	6,97	10,59	-96 040
6	6,95	10,59	-114 333
7	6,93	10,57	-118 907
8	6,91	10,55	-123 480
9	6,90	10,53	-128 053
10	6,88	10,51	-132 627
11	6,86	10,49	-137 200
12	6,84	10,47	-141 773
13	6,82	10,44	-146 347
14	6,81	10,42	-150 920
15	6,79	10,40	-155 493
16	**6,77**	**10,38**	**-160 067**

MARGIN REQUIREMENT

When the window has slide down all nodes of the vector files, then the USD, EUR result vector is filled with values. The margin requirement for the combined position is the worst outcome in the USD, EUR result vector.

In this example this is equal to SEK -205 800. This value is taken from node 26 of the USD, EUR result vector and it corresponds to the scenario were the USDSEK spot rate goes down to 6,59 and the EURSEK spot rate goes down to 10,18.

It should be noted that a margin requirement of SEK -205 800 is approximately 43% compared to the margin requirement given if the net present values had been converted independent of each other.

Figure: The margin requirement is the worst outcome within the USD, EUR result vector.

USD, EUR result vector

Node	USDSEK	EURSEK	NPV (SEK)
1	7,04	10,59	-22 867
2	7,02	10,59	-41 160
3	7,01	10,59	-59 453
4	6,99	10,59	-77 747
5	6,97	10,59	-96 040
6	6,95	10,59	-114 333
7	6,93	10,57	-118 907
8	6,91	10,55	-123 480
9	6,90	10,53	-128 053
10	6,88	10,51	-132 627
11	6,86	10,49	-137 200
12	6,84	10,47	-141 773
13	6,82	10,44	-146 347
14	6,81	10,42	-150 920
15	6,79	10,40	-155 493
16	6,77	10,38	-160 067
17	6,75	10,36	-164 640
18	6,73	10,34	-169 213
19	6,68	10,32	-173 787
20	6,66	10,30	-178 360
21	6,64	10,28	-182 933
22	6,62	10,26	-187 507
23	6,60	10,24	-192 080
24	6,59	10,22	-196 653
25	6,59	10,20	-201 227
26	**6,59**	**10,18**	**-205 800**
27	6,59	10,16	-192 080
28	6,59	10,14	-178 360
29	6,59	10,12	-164 640
30	6,59	10,09	-150 920
31	6,59	10,07	-137 200

Appendix IV

A guide to margin replication using interface files

Through the API, NOMX offers access to risk cubes which can be used to replicate the margin calculation exactly. These risk cubes are also available as interface files. In this appendix we will focus on information from queries EQ10, JQ16, JQ40 and JQ41. With this information CFM margin can be fully replicated.

EQ10 (interface file *.YCT)

This query answer/interface file contains information regarding the curves used in the CFM calculation. When replicating margins we are foremost interested in the information it holds about which curves are correlated. The curve identification codes are found in the first column, and the corresponding window group (if any) can be found in the second column.

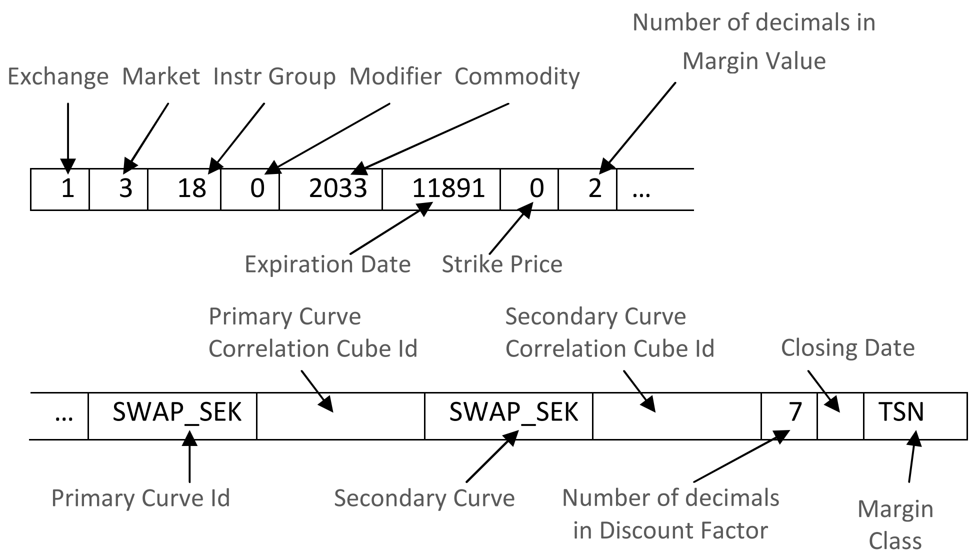
JQ16 (Interface file *.CCT)

This query answer/interface file describes the different window groups. Most importantly, in the third, fourth and fifth column the window size in each principal component dimension is found. In the second column, the upper window group (if any) can be found.

JQ40 (interface file *.RCT)

This query answer/interface file contains instrument series specific information used in the margin calculation. The file is only available for instruments with standardized series. For OTC-style contracts, see JQ41 below.

The first row contains metadata. Please study the example below, for the instrument series FRAO12.



The following data rows each represent one of the curve scenarios. If, for example, the scanning range is 5 in each principal component dimension, there will be 5*5*5 = 125 rows.

These data rows can be divided into three parts;

- the first three columns described the stress applied to the yield curve, Where 0 indicates that the PC was stressed to its minimum level. If the resolution is 5 in each PC, 4 indicates that the PC was stressed to its maximum leve, and 2 indicates no stress in the PC.

Stress in each principal component - PC1 PC2 PC3

Scenarios

PC1	PC2	PC3
0	0	0
0	0	1
0	0	2
0	0	3
0	0	4
0	1	0
0	1	1
0	1	2
0	1	3
0	1	4
0	2	0
…	….	…

- The next six columns describe the NPV for the "unknown" part of the instrument. This means the floating cash flow of a FRA, and the bond cash flows of a bond forward. NB, this is a NPV and does not need to be discounted further. The six columns represent the six combinations of whether the position is long or short, and of whether the calculations are made under a low, mid or high volatility stress. Note that for all instruments except options, it suffices to use the first two of these six columns. When interpreting the figures, the field *Number of Decimals in Margin Value* from the meta data row has to be used. In this example it is 2, meaning that the NPV of the floating cash flow in one (1) long position in the FRAO12 in scenario number 1 is 6569,33 SEK.

Scenarios

Volatility:	Low	Low	Mid	Mid	High	High
Position:	Long	Short	Long	Short	Long	Short
	656933	-656933	656933	-656933	656933	-656933
	648636	-648636	648636	-648636	648636	-648636
	640375	-640375	640375	-640375	640375	-640375
	632120	-632120	632120	-632120	632120	-632120
	623876	-623876	623876	-623876	623876	-623876
	670887	-670887	670887	-670887	670887	-670887
	662619	-662619	662619	-662619	662619	-662619
	654348	-654348	654348	-654348	654348	-654348
	…	…	…	…	…	…

- The last two columns contain the discount factors used to calculate the NPV of the contracted cash flow for long and short positions respectively. Since the contracted rate depends on when the contract was entered, it is left to the replicating agent to determine the undiscounted contracted cash flow. When interpreting these figures, remember to use the field *Number of Decimals in Discount Function* in the first meta data row. In this example the number of decimals in the discount function is 7, so the discount function for a long position in scenario 1 would be 0,9747635.

JQ40 is clearing house specific. Different members will get the same response from JQ40, since it covers the margin calculations of standardized contracts. When it comes to cleared OTC derivatives, whose contract details vary greatly between different trades, member specific risk cubes / interface files are needed. This need is covered by JQ41

JQ41 (INTERFACE FILE *.CRV)

This query answer/interface file contains margin calculation information for cleared OTC-trades, such as repos and swaps. The answer/file has one meta data row per curve, one per trade, and thereafter one row for each scenario (which currently makes 2 + 125 = 127 rows), multiplied by the number of cleared OTC-trades.

The metadata rows contain the information needed to identify the trade and to interpret the scenario margin figures. The first of these rows is similar in design to the metadata row in JQ40. The second metadata row contains the clearing account code and the trade number.

The following data rows each represent one of the curve scenarios. If, for example, the scanning range is 5 in each principal component dimension, there will be 5*5*5 = 125 rows per trade. There are six columns in each row, the first three describing the combination of principal component stress in that specific scenario. The three rightmost columns represent the NPV for the trade under three volatility regimes. Notice that if the cleared trade is not an option, the NPV will be the same for all three of the rightmost columns.

REPLICATING NAKED MARGIN

Naked margin in CFM means the margin that is the result of one position or trade being stressed in isolation. To replicate the naked margin follow these steps:

- For positions in standardized contracts, first calculate the contracted cash flow. Then use the appropriate discount factor in JQ40 to calculate its NPV in each curve scenario.
- For positions in standardized contracts, then calculate the “unknown” part of the instrument. For FRAs this means the floating cash flow, for bond forwards this means the NPV of the bond cash flows. This is done through multiplying the value in the corresponding column (long or short) with the number of contracts in the net position, after dividing it with 10^(Number of decimals in Margin Value).

- For positions in standardized contracts, then calculate the total NPV for each scenario by adding the two values above. The vector that is the result we shall hereafter refer to as the **stressed NPV vector**.
- For OTC-trades, all the information needed to create the **stressed NPV vector** can be found in the Margin Value columns in JQ 41, after dividing them with 10^(Number of decimals in Margin Value).
- Finally, we can now find the naked margin per position/trade by choosing the lowest value from the stressed NPV vector.
- NB, for derivatives where both the primary and secondary curves are used for discounting, (e.g. repos and bond forwards) and where these curves are different, one needs to take the worst of all NPVs of the contracted rate and the worst of all NPVs of the bond cash flows, and add these together to get the naked margin.

REPLICATING MARGIN

The correlation benefits in CFM can be said to occur on two levels.

On a curve level, there is a strong built-in correlation, which applies to all positions and trades priced against the same curve.

On an inter curve level, there is the possibility of configuring a correlation in terms of putting a limit on how much the applied stress can vary for curves within the same window group. The theoretical workings have been described above, here we will focus on how to achieve this effect with the help of the interface files.

The first step in replicating the margin is to aggregate all trades and positions that are priced against the same curve. This is done by creating one stressed NPV vector per curve, by adding together all of the stressed NPV vectors for the clients positions and trades that are margined against this curve. We hereafter call this aggregated vector the **curve stressed NPV vector.**

The second step of applying the correlation in between curves requires more attention to detail. One needs to perform the shifting of a smaller cube (representing the size of the window group) within a larger cube (representing the total set of stress scenarios), but in just one dimension (in the set of stressed NPV vectors). What is required is a method that translates the set of neighboring nodes in a certain node of the cube, to rows in the vector file.

Below is the description of a function, which can be called recursively to solve this problem - finding the window group members for row n in the the stressed NPV vector for a scenario space of size X*Y*Z, and a correlation window group of size x*y*z. X, Y, Z and x, y, z are all odd numbers. The list of scenarios is ordered in the same way as in the interface files, that is starting from negative stress in PC1 and ending with positive stress in PC3.

```
function [ neighbours ] = neighbours( n, w_size, step , mod)

    neighbours = [];

    %Loop through the list of rows
    for i=1:size(n,2)

        %find the "level" of the current row, to be able to distinguish
        %points outside the cube
        level = floor((n(i)-1)/mod);

        %find the neighbours in this dimension
        w = [-(w_size-1)/2:1:(w_size-1)/2];
        new_neighbours = n(i) + step*w;

        %remove the neighbours which fall outside the given "level"
        new_neighbours = new_neighbours(floor((new_neighbours-1)/mod) == level);
        neighbours = [neighbours, new_neighours];
    end
end


scenarios = neighbours( neighbours( neighbours(n,z,1,Z)...
                                    ,y,Z,Y*Z)…
                        ,x,Y*Z,X*Y*Z);
```

On the following pages, also find a list of which rows that are neighbors to a certain row in a framework where the total number of scenarios are 125 (5*5*5) and the size of the window correlation cube is 27 (3*3*3).

Row	Rows that are neighbours in a 3*3*3 correlation cube
1	1, 2, 6, 7, 26, 27, 31, 32
2	1, 2, 3, 6, 7, 8, 26, 27, 28, 31, 32, 33
3	2, 3, 4, 7, 8, 9, 27, 28, 29, 32, 33, 34
4	3, 4, 5, 8, 9, 10, 28, 29, 30, 33, 34, 35
5	4, 5, 9, 10, 29, 30, 34, 35
6	1, 2, 6, 7, 11, 12, 26, 27, 31, 32, 36, 37
7	1, 2, 3, 6, 7, 8, 11, 12, 13, 26, 27, 28, 31, 32, 33, 36, 37, 38
8	2, 3, 4, 7, 8, 9, 12, 13, 14, 27, 28, 29, 32, 33, 34, 37, 38, 39
9	3, 4, 5, 8, 9, 10, 13, 14, 15, 28, 29, 30, 33, 34, 35, 38, 39, 40
10	4, 5, 9, 10, 14, 15, 29, 30, 34, 35, 39, 40
11	6, 7, 11, 12, 16, 17, 31, 32, 36, 37, 41, 42
12	6, 7, 8, 11, 12, 13, 16, 17, 18, 31, 32, 33, 36, 37, 38, 41, 42, 43
13	7, 8, 9, 12, 13, 14, 17, 18, 19, 32, 33, 34, 37, 38, 39, 42, 43, 44
14	8, 9, 10, 13, 14, 15, 18, 19, 20, 33, 34, 35, 38, 39, 40, 43, 44, 45
15	9, 10, 14, 15, 19, 20, 34, 35, 39, 40, 44, 45
16	11, 12, 16, 17, 21, 22, 36, 37, 41, 42, 46, 47
17	11, 12, 13, 16, 17, 18, 21, 22, 23, 36, 37, 38, 41, 42, 43, 46, 47, 48
18	12, 13, 14, 17, 18, 19, 22, 23, 24, 37, 38, 39, 42, 43, 44, 47, 48, 49
19	13, 14, 15, 18, 19, 20, 23, 24, 25, 38, 39, 40, 43, 44, 45, 48, 49, 50
20	14, 15, 19, 20, 24, 25, 39, 40, 44, 45, 49, 50
21	16, 17, 21, 22, 41, 42, 46, 47
22	16, 17, 18, 21, 22, 23, 41, 42, 43, 46, 47, 48
23	17, 18, 19, 22, 23, 24, 42, 43, 44, 47, 48, 49
24	18, 19, 20, 23, 24, 25, 43, 44, 45, 48, 49, 50
25	19, 20, 24, 25, 44, 45, 49, 50
26	1, 2, 6, 7, 26, 27, 31, 32, 51, 52, 56, 57
27	1, 2, 3, 6, 7, 8, 26, 27, 28, 31, 32, 33, 51, 52, 53, 56, 57, 58
28	2, 3, 4, 7, 8, 9, 27, 28, 29, 32, 33, 34, 52, 53, 54, 57, 58, 59
29	3, 4, 5, 8, 9, 10, 28, 29, 30, 33, 34, 35, 53, 54, 55, 58, 59, 60
30	4, 5, 9, 10, 29, 30, 34, 35, 54, 55, 59, 60
31	1, 2, 6, 7, 11, 12, 26, 27, 31, 32, 36, 37, 51, 52, 56, 57, 61, 62
32	1, 2, 3, 6, 7, 8, 11, 12, 13, 26, 27, 28, 31, 32, 33, 36, 37, 38, 51, 52, 53, 56, 57, 58, 61, 62, 63
33	2, 3, 4, 7, 8, 9, 12, 13, 14, 27, 28, 29, 32, 33, 34, 37, 38, 39, 52, 53, 54, 57, 58, 59, 62, 63, 64
34	3, 4, 5, 8, 9, 10, 13, 14, 15, 28, 29, 30, 33, 34, 35, 38, 39, 40, 53, 54, 55, 58, 59, 60, 63, 64, 65
35	4, 5, 9, 10, 14, 15, 29, 30, 34, 35, 39, 40, 54, 55, 59, 60, 64, 65
36	6, 7, 11, 12, 16, 17, 31, 32, 36, 37, 41, 42, 56, 57, 61, 62, 66, 67
37	6, 7, 8, 11, 12, 13, 16, 17, 18, 31, 32, 33, 36, 37, 38, 41, 42, 43, 56, 57, 58, 61, 62, 63, 66, 67, 68
38	7, 8, 9, 12, 13, 14, 17, 18, 19, 32, 33, 34, 37, 38, 39, 42, 43, 44, 57, 58, 59, 62, 63, 64, 67, 68, 69
39	8, 9, 10, 13, 14, 15, 18, 19, 20, 33, 34, 35, 38, 39, 40, 43, 44, 45, 58, 59, 60, 63, 64, 65, 68, 69, 70
40	9, 10, 14, 15, 19, 20, 34, 35, 39, 40, 44, 45, 59, 60, 64, 65, 69, 70
41	11, 12, 16, 17, 21, 22, 36, 37, 41, 42, 46, 47, 61, 62, 66, 67, 71, 72
42	11, 12, 13, 16, 17, 18, 21, 22, 23, 36, 37, 38, 41, 42, 43, 46, 47, 48, 61, 62, 63, 66, 67, 68, 71, 72, 73
43	12, 13, 14, 17, 18, 19, 22, 23, 24, 37, 38, 39, 42, 43, 44, 47, 48, 49, 62, 63, 64, 67, 68, 69, 72, 73, 74
44	13, 14, 15, 18, 19, 20, 23, 24, 25, 38, 39, 40, 43, 44, 45, 48, 49, 50, 63, 64, 65, 68, 69, 70, 73, 74, 75
45	14, 15, 19, 20, 24, 25, 39, 40, 44, 45, 49, 50, 64, 65, 69, 70, 74, 75
46	16, 17, 21, 22, 41, 42, 46, 47, 66, 67, 71, 72
47	16, 17, 18, 21, 22, 23, 41, 42, 43, 46, 47, 48, 66, 67, 68, 71, 72, 73
48	17, 18, 19, 22, 23, 24, 42, 43, 44, 47, 48, 49, 67, 68, 69, 72, 73, 74
49	18, 19, 20, 23, 24, 25, 43, 44, 45, 48, 49, 50, 68, 69, 70, 73, 74, 75
50	19, 20, 24, 25, 44, 45, 49, 50, 69, 70, 74, 75
51	26, 27, 31, 32, 51, 52, 56, 57, 76, 77, 81, 82
52	26, 27, 28, 31, 32, 33, 51, 52, 53, 56, 57, 58, 76, 77, 78, 81, 82, 83
53	27, 28, 29, 32, 33, 34, 52, 53, 54, 57, 58, 59, 77, 78, 79, 82, 83, 84
54	28, 29, 30, 33, 34, 35, 53, 54, 55, 58, 59, 60, 78, 79, 80, 83, 84, 85
55	29, 30, 34, 35, 54, 55, 59, 60, 79, 80, 84, 85
56	26, 27, 31, 32, 36, 37, 51, 52, 56, 57, 61, 62, 76, 77, 81, 82, 86, 87
57	26, 27, 28, 31, 32, 33, 36, 37, 38, 51, 52, 53, 56, 57, 58, 61, 62, 63, 76, 77, 78, 81, 82, 83, 86, 87, 88
58	27, 28, 29, 32, 33, 34, 37, 38, 39, 52, 53, 54, 57, 58, 59, 62, 63, 64, 77, 78, 79, 82, 83, 84, 87, 88, 89
59	28, 29, 30, 33, 34, 35, 38, 39, 40, 53, 54, 55, 58, 59, 60, 63, 64, 65, 78, 79, 80, 83, 84, 85, 88, 89, 90
60	29, 30, 34, 35, 39, 40, 54, 55, 59, 60, 64, 65, 79, 80, 84, 85, 89, 90
61	31, 32, 36, 37, 41, 42, 56, 57, 61, 62, 66, 67, 81, 82, 86, 87, 91, 92
62	31, 32, 33, 36, 37, 38, 41, 42, 43, 56, 57, 58, 61, 62, 63, 66, 67, 68, 81, 82, 83, 86, 87, 88, 91, 92, 93
63	32, 33, 34, 37, 38, 39, 42, 43, 44, 57, 58, 59, 62, 63, 64, 67, 68, 69, 82, 83, 84, 87, 88, 89, 92, 93, 94
64	33, 34, 35, 38, 39, 40, 43, 44, 45, 58, 59, 60, 63, 64, 65, 68, 69, 70, 83, 84, 85, 88, 89, 90, 93, 94, 95

65	34, 35, 39, 40, 44, 45, 59, 60, 64, 65, 69, 70, 84, 85, 89, 90, 94, 95
66	36, 37, 41, 42, 46, 47, 61, 62, 66, 67, 71, 72, 86, 87, 91, 92, 96, 97
67	36, 37, 38, 41, 42, 43, 46, 47, 48, 61, 62, 63, 66, 67, 68, 71, 72, 73, 86, 87, 88, 91, 92, 93, 96, 97, 98
68	37, 38, 39, 42, 43, 44, 47, 48, 49, 62, 63, 64, 67, 68, 69, 72, 73, 74, 87, 88, 89, 92, 93, 94, 97, 98, 99
69	38, 39, 40, 43, 44, 45, 48, 49, 50, 63, 64, 65, 68, 69, 70, 73, 74, 75, 88, 89, 90, 93, 94, 95, 98, 99, 100
70	39, 40, 44, 45, 49, 50, 64, 65, 69, 70, 74, 75, 89, 90, 94, 95, 99, 100
71	41, 42, 46, 47, 66, 67, 71, 72, 91, 92, 96, 97
72	41, 42, 43, 46, 47, 48, 66, 67, 68, 71, 72, 73, 91, 92, 93, 96, 97, 98
73	42, 43, 44, 47, 48, 49, 67, 68, 69, 72, 73, 74, 92, 93, 94, 97, 98, 99
74	43, 44, 45, 48, 49, 50, 68, 69, 70, 73, 74, 75, 93, 94, 95, 98, 99, 100
75	44, 45, 49, 50, 69, 70, 74, 75, 94, 95, 99, 100
76	51, 52, 56, 57, 76, 77, 81, 82, 101, 102, 106, 107
77	51, 52, 53, 56, 57, 58, 76, 77, 78, 81, 82, 83, 101, 102, 103, 106, 107, 108
78	52, 53, 54, 57, 58, 59, 77, 78, 79, 82, 83, 84, 102, 103, 104, 107, 108, 109
79	53, 54, 55, 58, 59, 60, 78, 79, 80, 83, 84, 85, 103, 104, 105, 108, 109, 110
80	54, 55, 59, 60, 79, 80, 84, 85, 104, 105, 109, 110
81	51, 52, 56, 57, 61, 62, 76, 77, 81, 82, 86, 87, 101, 102, 106, 107, 111, 112
82	51, 52, 53, 56, 57, 58, 61, 62, 63, 76, 77, 78, 81, 82, 83, 86, 87, 88, 101, 102, 103, 106, 107, 108, 111, 112, 113
83	52, 53, 54, 57, 58, 59, 62, 63, 64, 77, 78, 79, 82, 83, 84, 87, 88, 89, 102, 103, 104, 107, 108, 109, 112, 113, 114
84	53, 54, 55, 58, 59, 60, 63, 64, 65, 78, 79, 80, 83, 84, 85, 88, 89, 90, 103, 104, 105, 108, 109, 110, 113, 114, 115
85	54, 55, 59, 60, 64, 65, 79, 80, 84, 85, 89, 90, 104, 105, 109, 110, 114, 115
86	56, 57, 61, 62, 66, 67, 81, 82, 86, 87, 91, 92, 106, 107, 111, 112, 116, 117
87	56, 57, 58, 61, 62, 63, 66, 67, 68, 81, 82, 83, 86, 87, 88, 91, 92, 93, 106, 107, 108, 111, 112, 113, 116, 117, 118
88	57, 58, 59, 62, 63, 64, 67, 68, 69, 82, 83, 84, 87, 88, 89, 92, 93, 94, 107, 108, 109, 112, 113, 114, 117, 118, 119
89	58, 59, 60, 63, 64, 65, 68, 69, 70, 83, 84, 85, 88, 89, 90, 93, 94, 95, 108, 109, 110, 113, 114, 115, 118, 119, 120
90	59, 60, 64, 65, 69, 70, 84, 85, 89, 90, 94, 95, 109, 110, 114, 115, 119, 120
91	61, 62, 66, 67, 71, 72, 86, 87, 91, 92, 96, 97, 111, 112, 116, 117, 121, 122
92	61, 62, 63, 66, 67, 68, 71, 72, 73, 86, 87, 88, 91, 92, 93, 96, 97, 98, 111, 112, 113, 116, 117, 118, 121, 122, 123
93	62, 63, 64, 67, 68, 69, 72, 73, 74, 87, 88, 89, 92, 93, 94, 97, 98, 99, 112, 113, 114, 117, 118, 119, 122, 123, 124
94	63, 64, 65, 68, 69, 70, 73, 74, 75, 88, 89, 90, 93, 94, 95, 98, 99, 100, 113, 114, 115, 118, 119, 120, 123, 124, 125
95	64, 65, 69, 70, 74, 75, 89, 90, 94, 95, 99, 100, 114, 115, 119, 120, 124, 125
96	66, 67, 71, 72, 91, 92, 96, 97, 116, 117, 121, 122
97	66, 67, 68, 71, 72, 73, 91, 92, 93, 96, 97, 98, 116, 117, 118, 121, 122, 123
98	67, 68, 69, 72, 73, 74, 92, 93, 94, 97, 98, 99, 117, 118, 119, 122, 123, 124
99	68, 69, 70, 73, 74, 75, 93, 94, 95, 98, 99, 100, 118, 119, 120, 123, 124, 125
100	69, 70, 74, 75, 94, 95, 99, 100, 119, 120, 124, 125
101	76, 77, 81, 82, 101, 102, 106, 107
102	76, 77, 78, 81, 82, 83, 101, 102, 103, 106, 107, 108
103	77, 78, 79, 82, 83, 84, 102, 103, 104, 107, 108, 109
104	78, 79, 80, 83, 84, 85, 103, 104, 105, 108, 109, 110
105	79, 80, 84, 85, 104, 105, 109, 110
106	76, 77, 81, 82, 86, 87, 101, 102, 106, 107, 111, 112
107	76, 77, 78, 81, 82, 83, 86, 87, 88, 101, 102, 103, 106, 107, 108, 111, 112, 113
108	77, 78, 79, 82, 83, 84, 87, 88, 89, 102, 103, 104, 107, 108, 109, 112, 113, 114
109	78, 79, 80, 83, 84, 85, 88, 89, 90, 103, 104, 105, 108, 109, 110, 113, 114, 115
110	79, 80, 84, 85, 89, 90, 104, 105, 109, 110, 114, 115
111	81, 82, 86, 87, 91, 92, 106, 107, 111, 112, 116, 117
112	81, 82, 83, 86, 87, 88, 91, 92, 93, 106, 107, 108, 111, 112, 113, 116, 117, 118
113	82, 83, 84, 87, 88, 89, 92, 93, 94, 107, 108, 109, 112, 113, 114, 117, 118, 119
114	83, 84, 85, 88, 89, 90, 93, 94, 95, 108, 109, 110, 113, 114, 115, 118, 119, 120
115	84, 85, 89, 90, 94, 95, 109, 110, 114, 115, 119, 120
116	86, 87, 91, 92, 96, 97, 111, 112, 116, 117, 121, 122
117	86, 87, 88, 91, 92, 93, 96, 97, 98, 111, 112, 113, 116, 117, 118, 121, 122, 123
118	87, 88, 89, 92, 93, 94, 97, 98, 99, 112, 113, 114, 117, 118, 119, 122, 123, 124
119	88, 89, 90, 93, 94, 95, 98, 99, 100, 113, 114, 115, 118, 119, 120, 123, 124, 125
120	89, 90, 94, 95, 99, 100, 114, 115, 119, 120, 124, 125
121	91, 92, 96, 97, 116, 117, 121, 122
122	91, 92, 93, 96, 97, 98, 116, 117, 118, 121, 122, 123
123	92, 93, 94, 97, 98, 99, 117, 118, 119, 122, 123, 124
124	93, 94, 95, 98, 99, 100, 118, 119, 120, 123, 124, 125
125	94, 95, 99, 100, 119, 120, 124, 125

To calculate the value in each row in the **total stressed NPV vector** for all positions and trades margined by curves that lie in the same window group, take the worst values from the neighboring rows in each **curve stressed NPV vector** and add them together.

Notice that this theoretically can be a recursive process, where a window group defining the correlation in between one set of curves, in a subsequent upper level step is correlated to other window groups or curves. Also note that there might exist parallel correlation structures that are not interconnected

Once the highest level in the correlation tree(s) have been reached, a number of stressed NPV vector are the end result. The end number of stressed NPV vectors is the number of top level window groups plus the number of curves that don't lie in any window group. The portfolio margin is replicated through taking the worst values from each of these vectors and adding them together.

NB, for derivatives where both the primary and secondary curves are used for discounting, (e.g. repos and bond forwards) and where these curves are different, one needs to let the NPVs of the contracted rate and the NPVs of the bond cash flows form part of their respective curve NPV vectors in order to replicate the margin calculation.