OSLO BØRS

OSLO STOCK EXCHANGE

JANUARY 2020

Oslo Børs - Core Bond Indices – Index Methodology

Issue 1.2

CONTENTS

1   INTRODUCTION

1.1 BACKGROUND

This booklet describes how Oslo Børs calculates the core bond indices. It is aimed at users, investors and others interested in the construction and computation of such indices.

1.2 DISCLAIMER

The information contained in this document is confidential, privileged and only for the information of the intended recipient and may not be used, published or redistributed without the prior written consent of Oslo Børs.

If, for some reason, an index is to be discontinued, Oslo Børs will notify the market in due course. A notice will be published at least six months before an index is to be discontinued, unless continuous calculation is not possible due to force majeure or other events outside the control of Oslo Børs. The decision to discontinue an index will be made by the Index Management Committee (IMC).

1.3 INFORMATION POLICY AND INDEX GOVERNANCE

Material changes to the index methodology are normally announced three months before they are put into effect. Examples of material changes to the methodology are changes to the price source, calculation formula and the index rebalancing requirements.

Oslo Børs may shorten the three months period for minor changes, or where the changes are the result of legislation, regulation, legal ruling, administrative decision or in other special cases.

IMC decides in each case whether an external consultation is necessary.

1.3.1   DAILY INDEX OPERATIONS

Daily index operations, such as running constituency weights calculations, quality checks and general surveillance of the daily production is performed by the Products Department. The index specialists within the Products Department also prepare documentation and data for decisions to be made by the IMC, as well as proposing changes in index rules and methodology. Periodical reviews and rebalancing of the indices are prepared by the Products Department and presented to IMC which is the decision-making body for all significant decisions affecting the index production. The index production is overseen by the Benchmark Oversight Committee (BOC).[1]

1.3.2   INDEX MANAGEMENT COMMITTEE (IMC)

The Index Management Committee will ensure an orderly and objective index maintenance. The committee is overseen by the Benchmark Oversight Committee (BOC)[2] and has the following responsibilities:
- Review and approve changes to the methodology
- Review and approve the semi-annual index rebalancing (only relevant for equity indices)
- Review and approve the handling of complex corporate actions, escalated by the Products Team

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[1] Please see footnote 3 below.
[2] Please see footnote 3 below.

- Approve or propose external consultations and review consultation feedback
- Decide when and to which extent the Advisory Group should be consulted
- Handle formal index related complaints, according to the "Oslo Børs Index Queries and Complaints Policy"

The Index Management Committee is internal, consisting of experienced staff from various Oslo Børs departments:
- Head of the Information Services department (the committee chair)
- Head of the Surveillance and Operations department
- Head of the Derivatives department
- Senior representative from the Secondary Market department

The committee is scheduled to meet twice a year and on ad-hoc basis when needed. Resolutions require the attendance of at least two regular members.

1.3.3   BENCHMARK OVERSIGHT COMMITTEE (BOC)[3]

The Benchmark Oversight Committee is responsible for independent oversight of all aspects of the governance of index administration. The committee has the following responsibilities:
- Report to the relevant competent authorities any misconduct by Oslo Børs as a Benchmark Administrator of which the oversight function becomes aware.

- Review the benchmarks' methodology at least annually.

- Oversee any changes to the benchmark methodology.

- Oversee the Benchmark Administrator's control framework, the management and operation of the benchmark.

- Review the decisions of the Index Management Committee and Products Team.

- Complete documentation shall be maintained for at least five years of all aspects of the governance and decisions of the Committee in a manner that makes it accessible for future reference.

The Benchmark Oversight Committee consists of experienced staff from various Euronext departments:
- Group Head of Compliance Euronext
- Group Head of Risk & Compliance
- Group Head of Regulation
- Group Finance Director

The Oversight Committee shall meet at least twice a year and whenever one or more of its members request a meeting. At least three members or deputy members are required to be present for the meeting to be quorate.

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[3] Oslo Børs is currently in the process of filing for registration as an index administrator pursuant to the Regulation (EU) 2016/1011 ("**BMR**"). The Benchmark Oversight Committee's functions will be effective from the date Oslo Børs has been formally registered as a BMR administrator.

1.3.4 INDEX CORRECTION POLICY

There are mainly three areas within Index Production that will require corrective measures; incidents concerning the real-time feed, incidents concerning the content of an index or incidents concerning the distribution of index weights.

More specifically, corrections may occur for instance due to wrong input prices or erroneous accrued interest, yield or duration. Incidents concerning the real-time market data feed is considered most critical.

Oslo Børs will correct any error as soon as possible and reissue index weight files and ensure correct closing and opening values. If the error is corrected during the market open, Oslo Børs will ensure correct real-time calculation.

The index correction policy requires reliable communication to market participants. Any corrections to index weight files or real-time dissemination will be communicated to the market participants directly or to the broader audience depending on scope of the incident and according to the overall contingency plans as a supervised entity. Communication will occur simultaneously to involved parties by e-mail and/ or the oslobors.no official webpage and distribution service.

1.4 CHANGE LOG

This document can be updated at any time, and has been through the following iterations:

Issue	Date	Description
1.1	29 December 2015	New document layout
1.2	16 September 2019	New sections added under section 1 Introduction

2 INDEX OVERVIEW

On March 1, 1995, Oslo Børs introduced five government bond indices. These are yield indices with a fixed duration of three months, six months, one year, three years and five years respectively. The aim of the government bond indices is to represent a reference for portfolios at each point of the term structure. Accordingly, the indices are not to be considered as investment objects. The indices are:

Symbol	Description	ISIN
ST1X	Government Bond Index, fix modified duration of 0.25 years	NO0000000138
ST2X	Government Bond Index, fix modified duration of 0.50 years	NO0000000146
ST3X	Government Bond Index, fix modified duration of 1.00 years	NO0000000153
ST4X	Government Bond Index, fix modified duration of 3.00 years	NO0000000161
ST5X	Government Bond Index, fix modified duration of 5.00 years	NO0000000179

2.1 ELIGIBLE SECURITIES

The selection of bonds eligible for index inclusion is based on the government bonds and treasury bills listed at the given time. Both serial and bullet bonds are eligible.

Two samples are made:
- A daily basis sample based on all the government bonds/treasury bills listed
- A daily index sample based on the basis sample and applied to each index respectively

2.1.1 BASIS SAMPLE

The prerequisites for the daily basis sample are set according to the following motives:
- Requirement regarding liquidity in order to secure good estimates of the value for the underlying instrument.
- Requirement regarding a reasonably number of securities in order to maintain the wanted properties of a portfolio.
- Secure that the sample is resilient against short periods of abnormal pricing (e.g. large spread).
- Work for a longer period of time. There has been a major change in the government bond market regarding concentration of a few bonds and total volume traded during the life span of the index.

Qualifying for the basis sample is made on a rolling basis and takes into account traded volume the last 15 market days (alternatively from the first day being listed).
- There must have been an end-of-day spread at least 1/3 of these days (independent of the type of trade)
- There must have been an end-of-day spread at least 2/3 of these days
- There must at least be registered one official trade or one end-of-day spread that satisfies a maximum spread requirement (please refer to Spread Requirements on page 12).

2.1.2 INDEX SAMPLE

An index sample is made for each index based on the basis sample. This delimitation is a result of the aim to exclude underlying securities which are not particularly representative to the index in question. The yield for a bond with duration of 6 years is e.g. often not comparable to yield for certificates. In addition, short term yields fluctuate more than long term yields.

In order to take these effects into consideration the index samples are delimited by a composed formula based on the duration of the index. The index sample is given by underlying bonds which have a duration within the interval: index duration +/- 0,5 (1 + index duration). The result of this is linear increasing intervals dependent on the duration of the index that range from (0, 0,88) for the shortest to (2, 8) for the longest index.

2.1.3 EXCEPTIONS

As far as possible, the index shall include at least one underlying bond on «each side» of the duration of the index even if the result of this should be that the underlying bond is beyond the interval of the index.

In the case where there are no underlying bonds at «each side» of the duration of the index, only the one underlying bond that has the lowest deviation from the index duration[4] is chosen. This is the only time where a fixed duration may not be maintained.

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[4] This has occurred during some periods for the shortest and the longest indices. The most significant was during fall 1992 when the duration of the 5-year index was close to 4.7 before ISIN NO100463 was issued.

3 INDEX WEIGHTS

Calculating the weights shall have the following characteristics:
- A fixed duration
- Giving the underlying bonds a relatively higher weight the closer these are to the duration of the index.

There is an unlimited amount of combinations that may be used in order to achieve a given duration for an index given that the following requirements are met (positive weights):
- At least 3 underlying bonds in the portfolio
- The distribution must be such that at least one of the underlying bonds measured by duration is on the other side of the others when related to the duration of the index.

The chosen solution corresponds with the properties which the indices are to satisfy.

The weights are set using a three-step process:
1. Divide the index sample into two portfolios dependent on «what side» of the index these are measured by duration.
2. Assign the underlying in each portfolio a weight relative to each other such that the weights become decreasing the greater the distance from the index measured by duration.
3. Reassign the portfolios' weights relative to each other with the result being that these combined equal the duration of the index.

Re 1:
The distribution relates to the duration of the underlying security. E.g. an index with a fixed duration of 3 will group all the underlying bonds in the index sample with a duration of less than 3 into portfolio 1 and the rest into portfolio 2.

Re 2:
Relatively declining weight may be set by using several methods such as linear or exponential declining weights. One has chosen to use the tail-probability for a hypothetical normal distribution as basis for calculating the weights for each underlying bonds in the portfolio. This formula is used due to the fact that it gives a heavy concentration around the chosen duration in addition to this function being well known.

It should be noted that in this case, the normal distribution does not have any direct financial interpretation, but is used due to the wanted properties of this function.

A normal distribution is given by two parameters:
- Average
- Standard deviation

Average is set to be equal to the duration of the index. Standard deviation is calculated as being a function of the duration of the index:

0,25*(1 + index duration). This will e.g. result in a standard deviation of 1 for the 3-year index. In comparison, the function which sets the index sample is given by +/- 2 standard deviations.

The weights for the two portfolios are set as follows:

$$W_i = \frac{z_i}{\displaystyle\sum_{i=1}^{n} z_i}$$

W_i = the underlying bond's weight in the portfolio

z_i = the positive difference between the duration of the index and the duration of the underlying bond measured by standard deviation

i = the tail probability for the normal distribution given by F(-zi), where F(x) is the cumulative probability function for the normal distribution.

n = the number of underlying bonds in the portfolio

Re 3:
Re-calculating the weights for the two portfolios into one.The following formula is used for calculating the weights of the portfolios:

$$d_{idx} = w_{p1} * d_{p1} + (1 - w_{p1}) * d_{p2}$$
$$\Downarrow$$
$$w_{p1} = \frac{d_{idx} - d_{p2}}{d_{p1} - d_{p2}}$$

d_{idx} = the duration of the index
d_{p1} = the duration of portfolio 1
d_{p2} = the duration of portfolio 2
W_{p1} = the weight of portfolio 1. The weight of portfolio 2 is thus given by (1-W_{p1})

In some cases a member gets more than 60% when using the algorithm described above. We will then proceed with a capping-algorithm for reducing the weight to 60%. This requires that we can distribute the excess weight to other index members and is therefore not always possible.
When describing this process later, we will call the side of the duration where capping is wanted, for 'capping-side' and the members for the capping portfolio.

Initially the member will receive a weight of 60%. The result is that the weights of the other members must be increased.

$$x * w_1 = M$$

M = max wanted weight for a single member in the index, 60%.

The weights for the remaining bonds in portfolio 1 must then be adjusted using a factor y:

$$y = \frac{1-x}{1-v_1}$$

v_1 = initial weight for bond 1 in portfolio 1

Adding these equations together, the following equation must be solved finding x:

$$\frac{M}{x} = \frac{d_{idx} - d_{p2}}{x d_1 + y (d_{p1} - v_1 d_1) - d_{p2}}$$

$$\Downarrow$$

$$x = \frac{M (d_{p2} (1 - v_1) - d_{p1} + v_1 d_1)}{M (d_1 - d_{p1}) - d_{idx} (1 - v_1) + d_{p2} (1 - v_1)}$$

d_1 = duration bond 1

The ratio for the weights between portfolio 1 and 2 in the index will then be adjusted according to:

$$w_1 = \frac{M}{x}$$

By multiplying the weights for each portfolio by the corresponding weights for the underlying bonds, the underlying bonds will in total represent one portfolio with duration equal to that of the index.

As this is an approximation formula, the duration measured by using one cash flow for the entire portfolio deviates somewhat (typically +/- 0,01/0,02 for the 5-year index). Any deviations are caused by skews of the term structure.

3.1 SPECIAL CASE WHEN THERE ARE FEW MEMBERS IN A PORTFOLIO

The model above will only give the wanted result if there are at least two members in the capping portfolio. It is necessary in order to readjust the weight from the bond that is being capped to the other bond(s) at the same side of the duration. Thus, if the capping-portfolio originally consists of only one member, an additional member may be added even though the duration of that member is outside of the defined boundaries.

In this case, the duration of portfolio 1 with two members is given by:

$$d_{p1} = v_1 d_1 + (1 - v_1) d_2$$

Using the equation above and solving x, we get:

$$x = \frac{M (d_{p2} - d_2)}{M (d_1 - d_2) - d_{idx} + d_{p2}}$$

Capping portfolio 2 are done using same rules, but taking into consideration that:

$$x (1 - w_1) = M$$

3.2 SPECIAL CASE WHERE THERE IS ONLY ONE MEMBER IN THE CAPPING PORTFOLIO

In order to be able to introduce capped weights, we need to have at least two members on the capping-side of the duration. If it only consists of one bond, no capping will be done, and the weight of the bond may be up to 100%.

3.3 CALCULATING THE VALUE OF THE UNDERLYING BOND

Only bids are used for calculating the value of the underlying bond.

The following algorithm is used for valuation:

if (bid)
closing price = bid

otherwise
closing price = initial price

Until 31. December 2004, the spread-evolve algorithm was used for the government bond indices.

3.3.1 INITIAL PRICE

Initial price is represented by a theoretical opening price. This is defined as the price which has the same yield when calculated at market day t as at the previous market day t-1.

IP_t = Initial price day t
r_t =   Accrued interest (accrued interest by staggered settlement   related to the number of settlement days)
y_t =   Yield calculated using closing price at day t
j_t =   The adjustment factor at last included record date before ex-coupon date. This is calculated as being discounted value of the coupon using the discount rate yt. Otherwise equal to 0
O_t =   The corresponding settlement day to market day t.
$O_t - O_t\text{-}1$ =   The number of calendar days between settlement days.

The reason that the calculations are based on yield is that this is a more comparable measure for the spread of the underlying securities with different duration. A recalculation into price has been chosen in order to simplify the real time calculations (avoids calculating yield for every price).

4   INDEX CALCULATION

Based on:

$$I_t = I_{t-1} * \sum_{i=1}^{n} W_{it} * \frac{P_{it} + r_{it}}{P_{it-1} + r_{it-1} - j_{it-1}}$$

I_t = The index value at day t
W_{it} = The weight of the index at day t for the underlying i
P_{it} = The price at day t for the underlying i
r_{it} = Accrued interest with settlement moved according to the number of settlement days for the underlying i
j_{it} = Adjustment factor at ex. coupon day
Pit-1 = Closing price at day t-1

Usually, the closing price at day t-1 will be the basis for the initial price at day t. There are exceptions where the underlying bond is «new» to the basis sample. The basis may then be a price which may have been quoted as far back as 15 days. Closing price at day t-1 and the initial price at day t is then calculated according to the following rules:

Basis:
1. The oldest official market price for the last 15 days.
2. If no. 1 does not exist, use the last spread that satisfies the spread requirements.

When this has been done, the closing prices, spread requirements, initial prices for each day up until day t-1 is simulated using the algorithms described above.

4.1 ADJUSTMENTS FOR THE SETTLEMENT-/MARKET DAY EFFECT

The yield for an index based on the closing price for one day related to the start value of the next day (using initial prices in the formula above) results in a yield where accrued interest is included. In a pure bonds index (2 settlement days) the return between closing value of Tuesday and start value of Wednesday will include 2 days of accrued interest as the corresponding settlement days are Thursday and Friday. The opposite effect occurs between the closing value of Friday and the starting value of Monday, where the corresponding settlement days are Tuesday and Wednesday. The result is an undesirable effect.

A general adjustment multiplier m for a pure bond index may be defined as:

$$m_t = \left(\frac{I_{startt}}{I_{closet-1}}\right)^{-\left(\frac{O_t - O_{t-1}}{b_t - b_{t-1}}\right)}$$

$I_{start\ t}$ =   Index value at day t using the initial prices in the formula
$I_{close\ t-1}$ =   Closing value of the index at day t-1
$b_t - b_{t-1}$ =   The number of calendar days between the trading days for closing calculation and start value
$O_t - O_{t-1}$ =   The number of calendar days between the corresponding settlement days

If the formula for the index calculation given above is multiplied by m_t, the result will be that the yield will reflect accrued interest according to the number of calendar days between closing value and start value.

4.2 FORMULA FOR INDEX CALCULATION

Taken the adjustments above into consideration, the formula is:

$$I_t = I_{t-1} * M_t * \sum_{i=1}^{n} W_{it} * \frac{P_{it} + r_{it}}{P_{it-1} + r_{it-1} - j_{it-1}}$$

M_t = The adjustment factor for settlement/market day effect

4.3 OTHER CALCULATIONS

As of March 1, 1995 the following information is published daily:
Yesterday's closing value, today's start value, the yield for each index and duration.

Yield and duration are calculated using initial prices for the same day. The calculations are based on the cash flows of the entire index where this is composed of the weighted cash flows for the underlying bonds. Adjustments are also made to take the different number of settlement days for certificates and bonds as underlying securities into effect.

5   PUBLISHING

The government bond indices are calculated in real time and distributed in the trading system during the trading day, i.e. 9 a.m. to 4 p.m.

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