MARKET DATA

Indices

JSE Fixed Income Index Series: Ground Rules

Ground Rules for the Management of the JSE Fixed Income Index Series

www.jse.co.za

Johannesburg
Stock Exchange

Contents

1 Index Series History

1.1 Key Milestones

The original compilation of the All Bond Index and its sub-indices was managed by Dr James Greener and developed in conjunction with the Actuarial Society of South Africa, with the initial index launch in July 2000.

The All Bond Index itself, as well as the original document from which the majority of this document draws its content, was originally compiled with assistance from Rogan Etheridge of Quant Financial Research. Please refer to *BEASSA Fixed Income Indices, August 2000, ASSA and BESA*. Professor Rob Thomson of the University of Witwatersrand provided the original impetus and mathematical principles via the Investment Committee of the Actuarial Society of South Africa.

Several gatherings of market participants were held in the course of preparing the original specification and their contributions are also noted with thanks. In particular, Jill Mann of Rand Merchant Bank acted as a continual spur to various participants in the process to keep focus and momentum. Glen Manning of JP Morgan provided advice and valuable information on the JP Morgan bond Indices.

Following the merger of the Bond Exchange of South Africa and the Johannesburg Stock Exchange in June 2009, the Composite Inflation Linked Index was the second composite index to be added to the Index Series, launching in September 2010. This also marked the first inclusion of inflation-linked bonds to the Index Series, with contributions made to the methodology by market participants in general, and the Actuarial Society of South Africa in particular.

August 2014 saw the introduction of several new composites to the Index Series, including a range of Credit Indices which excluded notes with a government guarantee. This marked the first inclusion of floating-rate notes to the Index Series. In addition, the Market Representation Methodology was introduced to provide complementary benchmarks to those produced by the existing Dual Ranking Methodology.

1.2 Credits

1.2.1 Actuarial Society of South Africa

The Actuarial Society of South Africa is the professional body of actuaries in South Africa. Actuaries play an important role in safeguarding the financial position of South African pension funds and insurers. Accurate measurement of the performance of these institutions' assets is essential. ASSA has had a long and successful association with BESA and the JSE, with significant input and ongoing involvement in indices for the local bond and equity markets.

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2 Governance

2.1 Role of the JSE

The JSE is the owner and Benchmark Administrator of the JSE Fixed Income Index Series. The JSE is responsible for all operational activities relating to the indices, including:

- Collection and verification of input data;
- Calculation and publication of index and constituent values;
- Production, application and publication of Reconstitutions and Reweightings;
- Maintenance and publication of the Index Series Ground Rules.

In addition, the JSE will maintain and develop the Index Series through the refinement of existing index rules, introduction of new rules and development of new indices.

2.2 Role of the Advisory Committee

The JSE Fixed Income Index Committee draws its members from the index investment community. Members are selected by the JSE for their knowledge and experience in the field and are drawn to represent industry experts, trading banks, asset managers and industry bodies such as the Actuarial Society of South Africa.

The mandate of the Index Committee is to oversee the accurate application of the index rules. The Index Committee meets quarterly to ratify the results of the Reconstitution. In addition, the Index Committee will advise the JSE on any concerns with, or proposed developments to, the Index Series. A summary of key discussion items is published to the JSE website shortly after each meeting.

3 Index Valuation

3.1 Index Series Function

The JSE Fixed Income Index Series is an independently calculated tool for investment managers operating in the debt security arena. Some of the key uses include:

3.1.1 A barometer for daily movements in the bond market

The various composite indices incorporate a wide range of maturities and coupon types, and provide a useful measure of the daily movement of the broader bond market. This is a better metric for performance than a single bond's yield or price movement. Individual bonds bear very specific supply and demand, credit, term and liquidity characteristics which may be different to the market as a whole.

3.1.2 A benchmark for measuring portfolio performance

Investors can measure the performance of their own portfolios against the performance of an appropriate index in the Index Series. Comparison allows the investor to measure their own performance relative to an independent market benchmark. An analysis according to term-splits may also provide the analyst with insight into which sections of the yield curve are responsible for excess or under-performance.

3.1.3 Analysing sub-sectors of the market

A wide range of composite indices is provided. In addition, sub-indices provide a more partitioned analysis by either Issuer Class or Term. These divisions ensure that a portfolio benchmarked against these sub-indices is not disadvantaged by differences in the term structure or credit spread of the composite indices.

3.1.4 Passive index tracking

A number of the composite indices are determined using a Dual Ranking methodology which includes liquidity in the selection criteria. This leads to these indices including the largest and most liquid issues and thus potentially facilitating the creation of passive index products.

3.2 Published Index Values

Several index metrics are published across the range of composite indices and their sub-indices, including:

- Total Return Index: this headline index value assumes that coupons are reinvested across the entire portfolio;
- Clean Price Index and All-in-Price Index: a representation of the capital value of the bond portfolio without regard for coupons paid. These should be similar to the performance of a bond portfolio that does not reinvest its coupons but rather pays them out to the investor;
- Coupon Yield: an estimate of the running yield of the bond portfolio;
- Average Yield: calculates the one yield that when used to value every bond in the index, produces the same index level;
- Duration and Convexity.

Index values are published daily after the completion of the JSE mark-to-market valuation process.

3.3 Performance Measurement

The JSE Fixed Income Indices can be used to measure performance between two dates. If the index on the first date is I_0 and on the second date it is I_1, then the return between these dates is given by the following formula:

$$P = \frac{I_1}{I_0} - 1$$

This measure of performance is given as a decimal, and is not annualised. This is the convention for periods of less than one year. If the period is greater than one year, it is convention to annualise the figure for return.

In the formula below, let t_0 be the first date, and let t_1 be the second date, both measured in days from the same base date such that the number of days between them can be found by subtraction. The formula for annualised performance of an index between two dates is given as follows:

$$P_{NACA} = \left(\frac{I_1}{I_0}\right)^{\frac{365}{t_1 - t_0}} - 1$$

This measure of performance is also a decimal and is stated as nominal annual and compounded annually (NACA). These units allow direct comparison with performance figures for other indices and other markets.

Sometimes it is preferable to state the performance measurement in terms of nominal annual compounded semi-annually (NACS) units. This is useful for those investors wanting to compare index performance directly to bond yields which are quoted in terms of nominal annual compounded semi-annually units as well. This measure is given as follows:

$$P_{NACS} = \left(\left(\frac{I_1}{I_0}\right)^{\frac{\frac{365}{2}}{t_1 - t_0}} - 1\right) \times 2$$

4 Index Family

4.1 Composite Index Categorisation

The various composite indices are defined according to broad categories. These categories are used to define the cross-section of the bond market being captured by each composite as well as the broad purpose of each index. The categories used are:

4.1.1 Coupon Type

Bonds with fundamentally differing coupon types are not included in the same index. Each index will therefore capture a single coupon type from the following:

- Fixed Rate: The bond pays a semi-annual coupon at a fixed, pre-defined rate (may be zero);
- Floating Rate: The bond pays a quarterly, non-amortising coupon with a fixed, pre-defined spread over JIBAR;
- Inflation-Linked Rate: The bond pays a semi-annual coupon at a fixed, pre-defined rate. However, the principal (and thus coupon amount) is inflated by a lagged CPI adjustment.

4.1.2 Guarantee Type

Bonds with an explicit government guarantee have different risk characteristics to those issued by corporates, parastatals or local authorities. Each index will capture one of the following guarantee types:

- Any Guarantee: The bond may, or may not, have an explicit government guarantee;
- Credit: The bond does not have an explicit RSA government guarantee. Indices in this category are referred to as "Credit Indices". Note that bonds issued by state-owned entities and municipalities do not necessarily incorporate an explicit RSA government guarantee, although this can be the case.

4.1.3 Replicability

The level of replicability of an index falls into one of the following broad categories:

- Replicable Indices: These indices are designed to be as replicable as possible, given the particular underlying universe of bonds. They generally have a fixed number of bonds as constituents. The constituents are selected using a Dual Ranking methodology which incorporates the total value traded of each bond as well as its issue size. Bonds which are very illiquid are thus unlikely to be included in the index. Some replicable indices have a 15% cap applied on individual issuer weight as well as a hard limit on the maximum number of bonds permitted per issuer;
- Representative Indices: These indices are designed to be as representative as possible of the underlying universe of bonds. A liquidity term is not utilised when selecting constituents, and thus individual bonds included in the index could be extremely illiquid. These indices are designed to capture a portion of the particular market segment based on a Market Representation Percentage (MRP) of 95%. As such, the largest 95% of all Issuers will be included in the index, based on clean market capitalisation.

Detailed information on the implementation of Dual Ranking and the Market Representation Percentage is included in Section 5.

4.2 Composite Indices

Composite indices are defined according to the three categories laid out above. There are currently seven composite indices in the Index Series, as follows:

Categorisation	Coupon Type		
	Fixed	Floating	Inflation-Linked
Replicable Indices			
Any Guarantee	ALBI20*		CILI15*
Credit	CFIX30	CFLO30	
Representative Indices			
Any Guarantee	ALBI95		
Credit	CFIX95	CFLO95	

*ALBI20 and CILI15 are defined as "Tradable Indices" since they have JSE-listed derivative products based on them.

The original two composite indices in the Index Series, namely the ALBI and CILI, have been renamed to the ALBI20 and CILI15 respectively. The original index names are still however valid, and ALBI can be used to refer to the ALBI20, and CILI to the CILI15.

A complete listing of the Composite Indices is provided below:

Code	Name	Coupon	Guarantee	Selection	Issuer Cap	Bond Cap
ALBI20	All Bond Index (ALBI)	Fixed	Any	Top 20 DR		
ALBI95	All Bond Market Index	Fixed	Any	95% MRP		
CILI15	Composite Inflation-Linked Index (CILI)	Inflation	Any	TOP 15 DR		
CFIX30	Credit Fixed Top 30 Index	Fixed	Credit	TOP 30 DR	15%	6
CFIX95	Credit Fixed Market Index	Fixed	Credit	95% MRP		
CFLO30	Credit Floating Top 30 Index	Floating	Credit	TOP 30 DR	15%	6
CFLO95	Credit Floating Market Index	Floating	Credit	95% MRP		

Detailed information on the implementation of Dual Ranking, the Market Representation Percentage and the Issuer and Bond Caps is included in Paragraph 5.

4.3 Sub-Indices

Each composite index will be further partitioned into a range of sub-indices. The categories used for this partitioning are:

4.3.1 Term to Maturity

Each bond in the composite index is allocated into one of four term buckets based on the outstanding term to maturity. For Fixed-rate notes and Inflation-linked notes:

- 1-3: The bond's term to maturity is greater than one year, but less than or equal to three;
- 3-7: The bond's term to maturity is greater than three years, but less than or equal to seven;
- 7-12: The bond's term to maturity is greater than seven years, but less than or equal to twelve;
- 12+: The bond's term to maturity is greater than 12 years.

For Floating-rate notes:

- 1-2: The bond's term to maturity is greater than one year, but less than or equal to two;
- 2-3: The bond's term to maturity is greater than two years, but less than or equal to three;
- 3-4: The bond's term to maturity is greater than three years, but less than or equal to four;
- 4+: The bond's term to maturity is greater than four years.

Each composite index will have exactly four term-split sub-indices such that every constituent of the composite index is also a constituent of exactly one term-split sub-index.

An individual instrument can move from one term-split to the next at any point in time based on its remaining term to maturity. This will be effective at the start of trading on the date that the instrument changes term-split, with k-factor changes occurring on the previous day.

4.3.2 Issuer Class

Each bond in the composite index is allocated into a single sub-index based on the broad category of issuer. The exact categorisation applied depends on the specific composite index as follows:

- ALBI20 is split into two Issuer class sub-indices:
  - ALBI20G ("GOVI") contains ALBI20 constituents ranked 1-10 at the quarterly Reconstitution that are issued by the Government of South Africa;
  - ALBI20O ("OTHI") contains all ALBI20 constituents that are not in the GOVI.
- ALBI95 and CILI15 are split into three Issuer Class sub-indices, namely:
  - Government Issuers (G),
  - State Owned Enterprise Issuers (S) and
  - Corporate Issues (C);
- CFIX30, CFIX95, CFLO30, CFLO95 are split into four Issuer Class sub-indices, namely:
  - Corporate – Financial (F)
  - Corporate - Non-Financial (N)
  - State-Owned Enterprises - including both Parastatals as well as Municipalities (S)
  - Asset-Backed Securities - refer to Special-Purpose Vehicles (A)

Each composite index will have two, three or four issuer class sub-indices such that every constituent of the composite index is also a constituent of exactly one issuer class sub-index.

4.4 Index Listing

The complete list of the 59 indices in the Index Series is as follows:

Code	Term Bucket sub-indices	Issuer Class sub-indices
ALBI20	ALBI201, ALBI203, ALBI207, ALBI2012	ALBI20G (GOVI), ALBI20O (OTHI)
ALBI95	ALBI951, ALBI953, ALBI957, ALBI9512	ALBI95G, ALBI95S, ALBI95C
CILI15	CILI151, CILI153, CILI157, CILI1512	CILI15G (IGOV), CILI15S (ISOE), CILI15C (ICOR)
CFIX30	CFIX301, CFIX303, CFIX307, CFIX3012	CFIX30F, CFIX30N, CFIX30S, CFIX30A
CFIX95	CFIX951, CFIX953, CFIX957, CFIX9512	CFIX95F, CFIX95N, CFIX95S, CFIX95A
CFLO30	CFLO301, CFLO302, CFLO303, CFLO304	CFLO30F, CFLO30N, CFLO30S, CFLO30A
CFLO95	CFLO951, CFLO952, CFLO953, CFLO954	CFLO95F, CFLO95N, CFLO95S, CFLO95A

5 Constituent Selection

5.1 Overview

Constituent additions and deletions occur quarterly at a Reconstitution; constituent weightings are updated monthly at a Reweighting.

The basic process applied at each Reconstitution is applied separately for each index, as follows:

1. Apply Core Eligibility criteria to all listed debt securities to obtain an eligible universe of bonds.
2. Select the constituents of the composite index from this universe, using either a Dual Ranking Methodology or a Market Representation Methodology.
3. If necessary, calculate an Issuer Capping Factor for each Issuer in the composite index.
4. Allocate each selected constituent of the composite index into the relevant Term-Split sub-index.
5. Allocate each selected constituent of the composite index into the relevant Issuer Class sub-index.

There are no constituent additions or deletions due to a Reweighting. However, the weighting factors for all constituents are updated, where their nominal amount in issue has changed, as well as their capping factors where relevant.

5.2 Definitions and Timelines

5.2.1 Reconstitution

A Reconstitution is performed quarterly for all indices in the Index Series, in February, May, August and November. At a Reconstitution, the constituents of each index are re-evaluated in line with these rules using either a Dual Ranking Methodology or a Market Representation Percentage Methodology, and set for the subsequent quarter. In addition, the weighting and capping factors are updated to reflect current bond data. Reconstitutions are effective after close of business on the first Thursday of reconstitution month. All changes made at each Reconstitution are published in advance by no later than the 15th day of the previous calendar month, subject to approval by the Index Committee.

As mentioned in section 4.2, ALBI20 and CILI15 are Tradable Indices with listed derivatives products. As such their reconstitutions are effective at 12 noon on the first Thursday of the Reconstitution month instead of after close of business.

Reconstitution dates are scheduled to coincide with bond option and future expiry dates to minimise the chances of constituent changes in the near contract.

5.2.2 Reweighting

A Reweighting is performed monthly in non-Reconstitution months, for all indices in the Index Series. It takes places in January, March, April, June, July, September, October and December. At a Reweighting, only the weighting factors of constituents are adjusted to reflect any updates to their nominal amounts in issue. Capping factors are recalculated where relevant. Reweightings are effective on the first day after the first Thursday of the Reweighting month. All weighting factor changes are made available to subscribers by no later than the 15th day of the previous calendar month.

5.2.3 Non-trading Days

Where the effective date of the Reconstitution or Reweighting falls on a non-trading day, this will be moved to the same calendar day in the following week. Where the new effective date in the following week is itself a non-trading day, the previous trading day in that week will be used.

5.2.4 Cut Date

The Cut Date is the last trading day of the month, two months prior to the Reconstitution or Reweighting month. For example, the Cut Date for the January Reweighting is the last trading day of the previous November, and the Cut Date for the February Reconstitution is the last trading day of the previous December.

5.2.5 Averaging Period

The Averaging Period is defined for each Reconstitution as the twelve month period ending on the Cut Date. In the case of new issues, the averaging period for that bond is calculated over the months for which is has been issued, excluding the first month of listing. Note that the Averaging Period is not used for a Reweighting.

5.3 Core Eligibility

5.3.1 Index Series Eligibility Criteria

To be eligible for selection for the JSE Fixed Income Index series, a bond must:

- Be listed on the JSE and settled electronically;
- Be a vanilla fixed rate, floating rate or inflation-linked bond. This excludes credit-linked notes, ETF's, commercial paper, perpetuities, customised instruments and amortising instruments;
- Have a remaining term to maturity greater than one year over the entire quarterly period for which the selection is made.
- Have a clean market capitalisation in excess of R100 million, measured over the averaging period;
- Have EITHER a single redemption date; OR, in the case of bonds with multiple redemption dates, be priced in the market according to the "mid-redemption" convention; and a redemption date (or mid-redemption date) which coincides with a coupon date;
- Be listed for at least 2 months on the Cut Date.

5.3.2 Index Specific Eligibility Criteria

Depending on the Coupon Type of the bond, it must satisfy the following eligibility criteria to be eligible for selection:

- For indices with Fixed Rate coupons, the bond must pay a semi-annual coupon at a fixed, pre-defined rate (may be zero);
- For indices with Inflation-Linked coupons, the bond must be a conventional CPI instrument which has a fixed (or zero) semi-annual coupon.
- For indices with Floating Rate coupons, the bond must pay a quarterly, non-amortising coupon at a fixed, pre-defined spread over JIBAR.

Any bond with an explicit guarantee by the Government of the Republic of South Africa will not be eligible for inclusion to the credit indices.

5.4 Reconstitution of Composite Indices

Composite Indices are reconstituted quarterly according to one of two methodologies. Replicable indices utilise the Dual Ranking methodology and consist of a fixed number of bonds. Representative indices utilise a Market Representation Percentage methodology and consist of a variable number of bonds. Each methodology is applied from first principles at each Reconstitution to determine the new constituents of the particular index. This can then be compared to the existing index constituents to determine if there are any constituent additions or deletions to be applied at that quarter.

5.4.1 Dual Ranking Methodology

The Dual Ranking Methodology is applied at Reconstitution separately for each index as required, according to the following steps:

1. Using bond data as published on the Cut Date, the Core Eligibility criteria are applied to determine a universe of eligible bonds for the particular index.
2. The Market Capitalisation of each eligible bond is calculated as the product of nominal amount in issue and clean price. This is done as at the end of each month in the Averaging Period, and then finally averaged to get an Average Market Capitalisation per bond.
3. Eligible bonds are ranked in descending order by Average Market Capitalisation and assigned a **Market Capitalisation Rank**. Ties are broken alphabetically by bond code.
4. The Liquidity of each eligible bond represents its secondary market turnover. This is given by the clean consideration of each trade. Trades included are outright purchases and sales of standard and odd lots, for settlement on the standard settlement day ("*t*+3"), or on any non-standard day. Both legs of carries (also known as buy/sell-backs), repos and option exercises are excluded. Liquidity is calculated as the median of the monthly traded values over the Averaging Period to get a Median Monthly Turnover per bond.
5. Eligible bonds are ranked in descending order by Median Monthly Turnover and assigned a **Liquidity Rank.** Ties are broken alphabetically-in-reverse by bond code.
6. The **Dual Rank** of a bond is the greater of its Market Capitalisation Rank and its Liquidity Rank. Ties of Dual Rank are likely, even common, and are broken by Market Capitalisation Rank. This can be simply achieved by adding 0.5 to the Market Capitalisation Rank of any bond whose Market Capitalisation Rank is greater than or equal to its Liquidity Rank. The Dual Rank is then the greater of this Adjusted Market Capitalisation Rank and the Liquidity Rank.
7. Eligible bonds are sorted by Dual Rank and the first N bonds so listed are selected. N will depend on the fixed number of constituents defined for the particular index.

5.4.2 Market Representation Percentage Methodology

The Market Representation Methodology is applied at Reconstitution separately for each index as required, according to the following steps:

1. Using bond data as published on the Cut Date, the Core Eligibility criteria are applied to determine a universe of eligible bonds for the particular index.
2. The Market Capitalisation of each eligible bond is calculated as the product of nominal amount in issue and clean price. This is done as at the end of each month in the Averaging Period, and then finally averaged to get an Average Market Capitalisation per bond.
3. An Issuer Market Capitalisation is calculated for each Issuer as the total of the Market Capitalisation for each bond issued by that issuer.
4. A Market Representation Percentage is calculated for each Issuer as the proportion of Issuer Market Capitalisation of the total eligible Market Capitalisation.
5. Issuers are sorted in descending order by Market Representation Percentage. The first N issuers are then selected such that their combined Market Representation Percentage is in excess of 95%. Just under 5% of issuers with the smallest Market Representation Percentages will thus be excluded from the index.

Note that selection occurs at an Issuer level and not at a bond level. If a particular Issuer falls within the 95% requirement then all its eligible bonds will be included in the particular Index.

5.5 Capping of Issuer Weight

A capping factor is applied in certain indices, as defined in Section 4.2. This capping factor determines the maximum weight of a single Issuer in the particular Composite Index. It is calculated at each Reconstitution and updated at each reweighting.

In practice, the capping factor is used to decrease the weighting factor (*i*.e. nominal amount in issue) used in the index calculation. As such, an individual bond may end up having a different weighting factor in two separate indices – one capped and one uncapped.

A single factor is calculated for each Issuer in each Index and then applied to all bonds issued by that Issuer. In other words the weight of each bond from that Issuer will be decreased by the same scale in that index.

5.6 Capping of Number of Bonds

A limit on the number of bonds per issuer is applied in certain replicable indices as defined in Section 4.2. This is applied in order to prevent crowding out of smaller issuers by those issuers who issue many bonds.

Upon ranking, an issuer is included in an index subject to a maximum of N bonds. This refers to the N largest bonds issued by a single issuer based on Dual Ranking.

5.7 Reconstitution of Sub-Indices

Any change to the constituents of a composite index at a Reconstitution will automatically have a knock-on impact on all sub-indices based on that particular composite index. Changes to sub-indices will be applied using the same values and timelines applied in the composite index.

5.8 Reweighting

The weighting factors of individual bonds are based on the nominal amount in issue of that bond. While this amount in issue can change from day-to-day, any such change will not be applied in the indices immediately. Instead, all changes will be rolled up and applied at the next Reweighting or Reconstitution. At each Reweighting, the weighting factor of each bond is updated to reflect the nominal amount in issue of that bond on the Cut Date. The capping factor will also be updated.

Note that all weighting factors are also updated at each Reconstitution, and as such, a Reconstitution can be seen to include a full Reweighting.

5.9 Treatment of Bond Split Options in Tradable Indices

In a small number of instances, bond issuers have in the past split the final redemption of a particular note over three distinct dates. In practice, this has been done by issuing three new bonds that replace the original bond. The three new bonds together would total the nominal value of the original bond, normally split equally three ways, and would redeem sequentially over three years.

When this occurs, the third child of a bond split will automatically replace its parent at the first Reconstitution following the final split, and will be ranked on its own merit thereafter

6 Special Events

In certain circumstances it might be necessary to consider the re-selection of constituents during a quarterly period. These circumstances could include (but are not limited to):

1. The early redemption or repurchase by the issuer of a large proportion of a bond's outstanding issue.
2. The issue of a new bond which is too large or important to have to wait for the next quarterly re-selection. This is based on the presumption that the bond will remain in the index.

In these and other extraordinary cases, the Index Committee will be convened to decide on a course of action. The decisions to be taken will include, among others:

- The new constituents of the sectors (which could however remain the same);
- Their new weightings (which could also be unchanged);
- The effective date for the change (if any);
- The amount of notice required (if applicable).

Any changes so introduced will be effective only until the next quarterly Reconstitution, at which point the standard rules will again apply. In making these decisions, the Index Committee will follow these guidelines:

- The overriding principle of the indices is that they track a portfolio of the constituent bonds in their given proportions. Hence any changes must be replicable by fund managers as far as practically possible.
- Liquidity is an issue. It may sometimes be unreasonable to expect fund managers to be able to move large amounts of stock. On the other hand, the very requirement to do so may create its own liquidity.
- The Index Committee will recognise that these specifications are unable to foresee all circumstances, and hence its discretion will be needed from time to time. However, these actions will form precedents, which will inform the Index Committee's subsequent deliberations.
- The Index Committee will communicate its decisions as soon as possible on the JSE website.

7 Calculation Guide

7.1 Overview

The specifications that follow use a “Reference Portfolio” rather than a “basic constant, k” which is often used in specifying indices. The two approaches are, however, mathematically equivalent.

The Reference Portfolio contains two classes of asset: bonds, and (from time to time) the rights to receive coupons. This right stems from bonds that are currently in their ex-coupon period, but were constituents of the index at the time that they entered the ex-coupon period. The weights of the bonds in the Reference Portfolio are proportional to their total nominal amounts in issue, and are updated monthly. This is the so-called “nominal weighting scheme”. Coupons vest on holdings of bonds on the days they go ex-coupon. They are received some time (usually 10 days) later and re-invested across the entire portfolio.

The Bond Portion of the portfolio is valued at all-in prices, using the appropriate market yields to maturity for the valuation date, for settlement on the standard settlement date (“t+3”). Coupons are valued by discounting them from receipt date to standard settlement date, at the yields to maturity of their parent bonds.

Bond and coupon values for the settlement date are then further discounted, at the yields to maturity of their respective bonds, to the valuation date.

7.2 Re-basing

Changes in the holdings of bonds in the Reference Portfolio are referred to as Re-basings. A Re-basing is an event that triggers a need for the index tracker to adjust their portfolio. This is an event which results in a k-factor change (see Section 7.3.13) and can occur for the following reasons:

1. Re-investment of coupons received.
2. Additions or Deletions of constituents in the index. This can be due to a Reconstitution, Term-split sub-index change or Special Event.
3. Change to the weighting of constituents to reflect changes in the nominal amount of bonds in issue. This can be done at a Reconstitution, Reweighting or due to a Special Event.

Re-basings are assumed to happen instantaneously at a fixed time on the last trading day before the change is effective (“re-basing time”). They take place at the yield to maturity determined by the JSE to hold at that time (“re-basing yield”). This would ordinarily be at 16:30 each day, using the mark-to-market yields to maturity determined by the JSE at that time. It may however be necessary to use different times on days when futures contracts expire, if they have a different expiry time. The 12:00 mark-to-market is currently used for Reconstitutions of tradable indices (as per section 4.2).

Index trackers are required to rebase their portfolios at the re-basing yield in order to avoid tracking error.

7.3 Total Return Index

7.3.1 Preface

The description which follows is designed for programmers writing to these specifications, rather than for the immediate edification of the reader. Therefore some prefatory explanation may be in order.

Sections 7.3.2 to 7.3.7 define basic concepts, from the time structure (valuation and settlement dates), through the nomenclature for bonds and their weights, and onto the initialisation of an index at its inception. The last of these sections defines the discount factors to be used between settlement and valuation date.

Section 7.3.8 describes the bond portion of the portfolio, in terms of the weights of each bond, and specifies how to value it.

Sections 7.3.9 to 7.3.12 deal with ex-coupons. First the ex-period is defined and then the quantification and valuation of ex-coupons portions during this period are specified. Lastly, the value of coupons being re-invested on any day is given.

Sections 7.3.13 and 7.3.14 give the central result: the calculation of the Nominal Factor on any day, to reflect coupons being re-invested and any change in weights. The same formula can be used even if there are no re-investments or weight changes.

"Index Value" in this section is taken to mean the Total Return Index Value.

7.3.2 Time Structure

Consider the calculation of the index value at a certain time on a certain date, the "Valuation Date", *t*[1]. The Valuation Date may be any day of the week, not necessarily a trading day. The calculation time is not parameterised, but is stated explicitly where it is not obvious from the context. For any date, *t*, define its settlement date, *s*, as follows:

- If *t* is a trading day, *s* is the date of its settlement day according to the then prevailing JSE practice. Currently bonds settle on "*t*+3" using the following good business day convention;
- If *t* is a non-trading day, *s* is deemed to be the settlement day of the first preceding trading day. For example, if *t* is a Saturday, *s* must be the settlement date for Friday *i*.e. the next Wednesday (assuming no public holidays).

However, it is important to bear in mind that in the valuation of floating rate notes, they are valued *t*+0, *i*.e. *t*=s.

Yields to maturity applicable to any calculation, unless explicitly stated, will be those prevailing at the time. For calculations on non-trading days the mark-to-market yields to maturity of the first preceding trading day will be used[2]. Nominal yields will be used for fixed and floating bonds and real yields for inflation-linked bonds.

7.3.3 Bonds

The constituent bonds of the index being calculated are referred to by the subscript *i*, or as "bond *i*", where *i* ranges from 1 to *N*, the number of constituent bonds. All summations (Σ) are over *i*=1 to *N*. *N* obviously differs between indices or even between valuation dates for the same index, and hence the description below is to be taken as referring to the calculation for only a single index or sub-index on a valuation date.

7.3.4 Weighting Factor

The weighting factors of the bonds in the index are given by:

$$w_{i,t}$$

Where the subscript *i* refers to bond *i* and the subscript *t* indicates the date.

$w_{i,t}$ is the nominal amount in issue of each bond measured in Rand Millions, decreased in some instances by an Issuer capping factor. This number is set and published monthly at each Reconstitution or Reweighting, and remains fixed for the subsequent month.

1 Dates such as *t* are expressed as the number of days from a fixed based date so that simple arithmetic can be performed on them

2 Yields are assumed to be given as percentages, so that a yield of 16.52% is the number 16.52. Division by 100, where necessary, is explicit in the calculations.

On days when a Reweighting, Reconstitution or term sub-sector changes take place, weights for some bonds could be zero either before or after the change. The specifications below allow for this. In fact, any number of extra bonds can be included in the N bonds, and as long as their weights are zero, they will not affect the results of the Bond Portion of the portfolio.

7.3.5 Inflation Factor

An inflation index ratio is needed to adjust certain values when calculating inflation-linked indices. It is important to note that the all-in prices for bonds published by the JSE are already adjusted for inflation, however an inflation index ratio is required in order to create a nominal discount factor from a real discount factor, as well as to calculate the actual cash-flow of an ex-coupon.

The inflation index ratio uses the CPI index, which is the headline CPI for all urban areas. This index is published monthly by Statistics South Africa in document P0141[3].

CPI(j) or the value of the CPI index ratio at a given time *j* is calculated as follows:

$$CPI(j) = \frac{\frac{m-d+1}{m} CPI_{M-4} + \frac{d-1}{m} CPI_{M-3}}{Base\ CPI_i}$$

Where:

j	is the date for which the CPI index ratio is needed
d	is the calendar day corresponding to j
m	is the number of days in the calendar month M
M	is the calendar month corresponding to j
CPI_X	is the published CPI index value that applies to the first day of the calendar month X
$Base\ CPI_i$	is the CPI index value for the base date of bond *i*; this is usually the issue date of the bond but may also be based on a reference bond.

7.3.6 Initialisation

An index is created as at the end of day on date t_0 with initial value I_{t0}. The Rand value of the Reference Portfolio at the same time is Z_{t0}. Indices are usually launched with an initial value of 100, although there is no reason why any other values cannot be used. The value of the Reference Portfolio "cancels out" in the calculations, and therefore its initial value can be almost anything. A convenient value is R100m, so that the portfolio value (in R millions) and the index value (if initially 100) are always the same number.

The base date for the ALBI20 and its sub-indices is 25 July 2000. The base date for the CILI15 and its sub-indices is 1 February 2007, with an initial index value of 100. This ensures that the index levels are somewhat comparable as their levels are identical on 1 February 2007. The base date for the ALBI95 and the Credit Indices is 1 April 2012.

7.3.7 Valuation Date Discount Factors

The calculations for day *t* start with the pricing of the constituent bonds in the Reference Portfolio for settlement on *s.* Similarly if there are any ex-coupons they will be discounted from their receipt date to give a value on *s*.

These values for *s* will then be further discounted from *s* to the valuation date *t*. The discounting of each value (*i*.e. bond price or ex-coupon belonging to the bond) will be at each bond's yield to maturity, including an inflation adjustment for inflation-linked bonds.

3 This index is subject to change and rebasing by Statistics South Africa. If the aforementioned index is not available, the relevant appropriate substitute index will be used

The effect of this further discounting will often be the same as if the bond itself had been valued for settlement on *t* and not on *s,* using the same yield to maturity[4]. In order to make this statement as true as possible, the discounting method applied from *s* to *t* must be consistent with the Bond Pricing Formula[5]. The specifications below describe the calculation of discount factors, $D_{i,t}$, for bond *i* on day *t*, which fulfil this condition.

The inputs are:

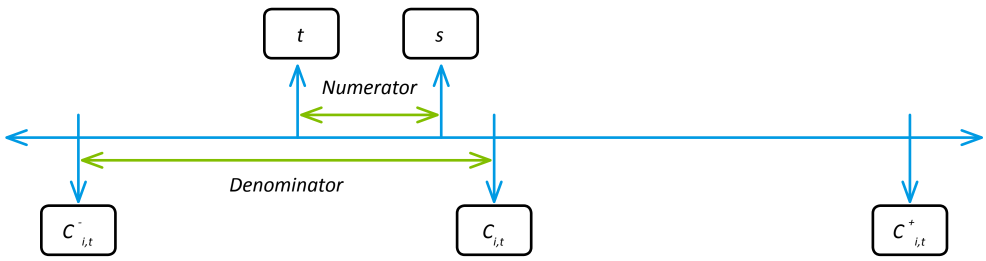
t	is valuation date
s	is settlement date for *t* (see 7.3.2)
$c_{i,t}$	is the first coupon payment date for bond *i* which is on or after *t*
$c^-_{i,t}$	is the previous coupon payment date for bond *i* which is before ci,*t*
$c^+_{i,t}$	is the first coupon payment date for bond *i* which is after ci,*t*
$Y_{i,t}$	is the yield to maturity of bond *i* applicable to the valuation. This figure will be the nominal yield to maturity for vanilla bonds and the real yield to maturity for inflation-linked bonds

The first step is to determine the exact size of the period, $H_{i,t}$, over which discounting is performed for bond *i* on day *t*. This is measured in the same units as the coupon frequency of the bond, namely half-years for the fixed rate and inflation-linked indices, and in quarter-years for the floating rate indices. This period size will correspond to the period between the previous and the next coupon dates and can vary in its actual number of days.

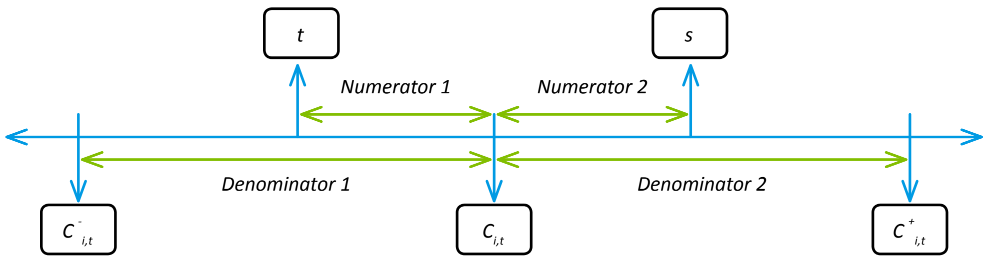
The period from *s* to *t* is then measured as a fraction of a half-year or a fraction of a quarter, rather than a fixed number of days. $H_{i,t}$ is used in conjunction with the bond's yield to maturity to determine a discount factor applicable from *s* to *t*.

If the period between *s* and *t* does not contain a coupon payment date, then $H_{i,t}$ is simply the number of days from *t* to *s* divided by the number of days in the current coupon period. However, if a coupon payment date does fall before the settlement date, we have to allow for two coupon periods of different lengths. These two cases are illustrated below:

a. No Coupon Between *s* and *t* (*i*.e $c_{i,t} \geq s$) :



b. Coupon Between *s* and *t* (*i*.e *t*≤ ci,*t* <s):



4 Results will differ only where valuation for *t* is cum, while that for *s* is ex.

5 Specifications for the Bond Pricing Formula are available from the JSE in a document of that name, as a hard copy or on their website.

Hence from the above, the formulae for $H_{i,t}$ is as follows:

$$H_{i,t} = \frac{s - t}{c_{i,t} - c_{i,t}^{-}} \qquad if\ c_{i,t} \geq s$$

$$H_{i,t} = \frac{s - c_{i,t}}{c_{i,t}^{+} - c_{i,t}} + \frac{c_{i,t} - t}{c_{i,t} - c_{i,t}^{-}} \qquad if\ c_{i,t} < s$$

Given $H_{i,t}$ above, the discount factor $D_{i,t}$ applicable from *s* to *s* is:

For Fixed Coupon Bonds: $$D_{i,t} = \left(\frac{1}{1+\frac{Y_{i,t}}{200}}\right)^{H_{i,t}}$$

For Inflation-Linked Bonds: $$D_{i,t} = \left(\frac{1}{1+\frac{Y_{i,t}}{200}}\right)^{H_{i,t}} \times \frac{CPI(t)}{CPI(s)}$$

For Floating Rate Bonds: $D_{i,t}$=1; The discount factor does not apply because floating rate notes are valued *t*+0, *i*.e. *t*=s.

7.3.8 The Bond Portion of the Portfolio

The reference portfolio is valued in two separate portions: the Bond Portion and the Ex-Coupon Portion. This section deals with the former.

The Bond Portion of the Portfolio is a portfolio of bonds *i* held in nominal amounts $N_{i,t}$ on day *t*. The nominal amount of Bond *i* on day *t* is proportional to that bond's weighting factor on the same day:

$$N_{i,t} = K_t \times w_{i,t}$$

K_t represents the proportionality constant or "k-factor". This acts as a rebasing factor for the index value, and is set at an index level. It is subject to change from time to time when a re-basing event occurs (see Section 7.3.13), however its initial value is given by the requirement that the portfolio's initial value is Z_{t0}:

$$K_{t_0} = \frac{Z_{t_0}}{\sum w_{i,t_0} \times P_{i,t_0} \times D_{i,t_0}}$$

In the above formula, $P_{i,t0}$ is the all-in price of bond *i* at its re-basing yield for day t_0, for settlement on *s*, and $w_{i,t0}$ are the weights applicable to t_0. Bond prices as defined in the Bond Pricing Formula are quoted per R100 nominal, and must be divided by 100 before being used here. For inflation-linked indices, the all-in-prices provided by the JSE will already include the CPI index ratio adjustment.

The value of the Bond Portion for a single bond, $B_{i,t}$, at any time on day *t* is then given by:

$$B_{i,t} = N_{i,t} \times P_{i,t} \times D_{i,t}$$

Where $P_{i,t}$ is the all-in price of bond *i* per R100 nominal, for settlement on day *s* at the prevailing yield to maturity. The total value of the Bond Portion of the Reference Portfolio is the sum of $B_{i,t}$ across all bonds:

$$B_t = \sum B_{i,t}$$

7.3.9 The Ex-Period

The Ex-Period of a bond is the period which occurs directly before each of its coupon payment dates when it is trading for settlement ex-coupon. The trader who purchases the bond in its ex-period is not entitled to receive the next coupon payable.

The Ex-Period begins on the first day on which a bond is trading for ex-settlement *i*.e. the first trading day whose settlement date is on or after the bond's books-closed date.

The Ex-Period ends on the day on which the coupon (having been received) can be re-invested *i*.e. the first trading day whose settlement is on or after the bond's coupon payment date. On this day the Ex-Period ends at the re-basing time for the day.

7.3.10 The Ex-Coupon of an individual bond

The Ex-Coupon portion of the portfolio on valuation date *t* is the value of coupons which have vested in the portfolio (based on holdings in the bonds at the start of their Ex-periods) but have not yet been received and re-invested.

The Ex-Coupon, $X_{i,t}$, relating to bond *i* on day *t* can be defined as follows:

For Bonds not in their Ex-period: $X_{i,t} = 0$

For Fixed Coupon Bonds: $$X_{i,t} = N'_{i,t} \times \frac{g_i}{200}$$

For Inflation-Linked Bonds: $$X_{i,t} = N'_{i,t} \times \frac{g_i}{200} \times CPI(C_{i,t})$$

For Floating Rate Bonds: $$X_{i,t} = N'_{i,t} \times \frac{g_i}{400}$$

Where:

$N'_{i,t}$	is the nominal amount of the bond in the portfolio on the first day, *t'*, of its Ex-Period (and before any Re-basing for that day)[6]. This value remains constant throughout the Ex-Period
g_i	is the coupon rate of bond *i*, expressed as a percentage. This will be a nominal coupon rate for fixed and floating rate bonds and a real coupon rate for inflation-linked bonds
$CPI(c_{i,t})$	is the CPI index ratio for the coupon payment date $c_{i,t}$ as defined in Section 7.3.5

Note: It is possible for a particular bond to be included in the ex-coupon portion but no longer a constituent of the Bond Portion of the portfolio, if it was deleted from the index during its ex-period.

6 Note that, at the launch of a new index, the fact that a bond may be in its Ex-period is ignored so that all Ex-Coupons are zero.

7.3.11 The Value of the Ex-Coupon Portion

The value of each bond's ex-coupon, $V_{i,t}$, on any day t in its Ex-Period, is the present value of that coupon payment discounted in two parts: first from coupon payment date to s and then from s to t. In the event where the coupon payment date falls between t and s, there is only a single level of discounting: from coupon payment date to t.

For Fixed Coupon Bonds:

$$V_{i,t} = X_{i,t} \times D_{i,t} \times \left(\frac{1}{1+\frac{Y_{i,t}}{200}}\right)^{\frac{\max(c_i - s,0)}{c_i - c_i^{-}}}$$

For Inflation-Linked Bonds:

$$V_{i,t} = X_{i,t} \times D_{i,t} \times \left(\frac{1}{1+\frac{Y_{i,t}}{200}}\right)^{\frac{\max(c_i - s,0)}{c_i - c_i^{-}}} \times \frac{CPI(s)}{CPI(c_{i,t})}$$

For Floating Rate Bonds, the ex-coupon portion is discounted using the zero-rate plus the trading spread in order to bring it to trade date:

$$V_{i,t} = X_{i,t} \times \left(\frac{1}{1 + \frac{Z_t + TS_{i,t}}{400}}\right)^{\frac{4 \times \max(c_i - t,0)}{365}}$$

Where:

Z_t is the zero-rate off the JSE Linear Swap Curve on day t

$TS_{i,t}$ is the trading spread for instrument i on day t

The total value of the Ex-Coupon portion of the Reference Portfolio is the sum of $V_{i,t}$ across all bonds:

$$C_t = \sum V_{i,t}$$

7.3.12 Re-investment of Coupons

The Ex-Coupon $X_{i,t}$ is received on its payment date and re-invested at the first opportunity thereafter, *i*.e. on the first trading date whose settlement date is on or after receipt date, or the last day of the Ex-Period.

It is important to note that due to the lag between trade and settlement, the deals to re-invest the coupons take place before the actual receipt date. Re-investment occurs at the Re-basing time and at Re-basing yields for the day. Until this happens, it is still part of the Ex-Coupon portion, C_t. After the Re-basing, it falls out of this portion.

The value of the Ex-Coupon portion that is to be re-invested on settlement date s is defined as $R_{i,t}$, and will thus only have a value on the last day of the Ex-period, being 0 elsewhere:

$R_{i,t} = V_{i,t}$ if t is the last day of the Ex-period

$R_{i,t} = 0$ otherwise

The total value of the coupons being re-invested across the Reference Portfolio is:

$$R_t = \sum R_{i,t}$$

7.3.13 Recalculation of the Nominal Factor, Kt

The recalculation of K_t takes place whenever there is a Re-basing event (Section 7.2), at the Re-basing time. The new k-factor, K_t' will hold thereafter[7].

K_t' is calculated such that the value of the Reference Portfolio immediately before and after the Re-basing is the same. The k-factor is thus used to maintain a continuous index value.

The k-factor is calculated as follows:

Portfolio after Re-Basing Changes = Portfolio before Re-Basing Changes

$$\sum K_t' w_{i,t}' P_{i,t} D_{i,t} + C_t' = \sum K_t w_{i,t} P_{i,t} D_{i,t} + C_t$$

$$K_t' \left(\sum w_{i,t}' P_{i,t} D_{i,t} \right) = B_t + R_t$$

$$K_t' = \frac{B_t + R_t}{\left(\sum w_{i,t}' P_{i,t} D_{i,t} \right)}$$

Where:

K_t'	is the new k-factor
$w_{i,t}'$	is the new weight applicable after the Re-basing event

7.3.14 Total Return Index Value

The Total Return Index value of the Reference Portfolio at any time on day *t* is given as follows:

$$Z_t = B_t + C_t$$

7.4 Clean Price Index

The clean price index is a representation of the capital value of the bond portfolio without regard for the interest accrued or coupons paid. This index is "clean" and is calculated as follows:

$$I_t = \frac{K_t \sum P_{i,t} \times W_{i,t}}{\sum W_{i,t}}$$

Where

I_t	is the value of the Clean Price Index at time *t*
$P_{i,t}$	is the clean price per R100 nominal value of constituent *i* at time *t*, priced for same day settlement (*i*.e *t*=s)
K_t	is the constant chosen to base the index at the published starting value as on the starting date of the index. This "k-factor" changes whenever index constituents or weightings change so that the index level is continuous. Thus, the new constant k' is calculated such that $I'_t = I_t$. Note that each index has a distinct k-factor and that the K_t used in the Clean Price Index is not the same as the K_t used in the Total Return Index

7 Generally, this would be from the next trading day. But, if real-time indices are to be calculated after the Rebasing on the same day, the new value K'_t must be used. In this case too, the value of the coupons which have been re-invested must not be included in the total value of the ex-coupons.

7.5 All in Price Index

The all in price index is identical to the clean price index, save for the fact that the all in price is used. This should reflect performance similar to that of a bond portfolio which does not reinvest its coupons but rather pays them out to the investor.

$$I_t = \frac{K_t \sum P_{i,t} \times W_{i,t}}{\sum W_{i,t}}$$

Where

I_t	is the value of the All in Price Index at time *t*
$P_{i,t}$	is the all in price per R100 nominal value of constituent *i* at time *t*, priced for same day settlement (*i*.e *t*=s)
K_t	is the constant chosen to base the index at the published starting value as on the starting date of the index. This "k-factor" changes whenever index constituents or weightings change so that the index level is continuous. Thus, the new constant k' is calculated such that $I'_t = I_t$. Note that each index has a distinct k-factor and that the K_t used in the All in Price Index is not the same as the K_t used in the Total Return Index

7.6 Coupon Yield Index

The coupon yield index provides a running yield estimate and is defined as the annual interest yield on the price index, *i*.e. the interest receivable over a full year divided by the market capitalisation.

For fixed-rate and floating-rate indices:

$$Y_t = \frac{\sum g_i \times W_{i,t}}{\sum P_{i,t} \times W_{i,t}}$$

For inflation-linked indices:

$$Y_t = \frac{\sum g_i \times P_{i,t} \times W_{i,t}}{\sum P_{i,t} \times W_{i,t}}$$

Where

g_i	is the coupon rate of bond *i*, expressed as a percentage. This will be a nominal coupon rate for fixed and floating rate bonds and a real coupon rate for inflation-linked bonds
$P_{i,t}$	is the clean price per R100 nominal value of constituent *i* at time *t*, priced for same day settlement (*i*.e *t*=s)

7.7 Average Yield Index

The average yield index calculates the one yield that when used to value every bond in the index, produces the same index level. It is therefore, the average yield attained by the index. For the vanilla indices, the average yield is calculated using only 5 iterations of the Newton-Bailey method as illustrated below. As a note, only positive iterations of the yield are considered. Negative values are set to zero:

$$Y_{i+1} = \left(\frac{Y_i}{100}\right) - \frac{I - I_i}{(I_i \times dMod_i) - \frac{((I - I_i) \times Conv_i)}{(2 \times dMod_i)}}$$

Where

Y_i	is the i^{th} iteration of the average yield (Y_0 is the largest of the constituent bond yields)
I_i	is the i^{th} iteration of the portfolio value calculated using Y_i as the yield for all of the constituent bonds
I	is the original index value which remains a constant
$dMod_i$	is the modified duration of the index i_i
$Conv_i$	is the convexity of the index I_i

7.8 Duration and Convexity

The calculation of the first and second differential of the bond or portfolio value, with respect to yield to maturity, is required for Duration and Convexity. Given the somewhat complex and detailed definitions of this value provided above, these differentials could be quite lengthy. However, whereas an exact valuation is crucial to the indices proper application, this is not the case with duration and convexity. These measures, which are usually quoted with only 2 or 3 significant digits, are used more to give an impressionistic view of a portfolio than to describe it precisely.

Furthermore, it is becoming widely accepted that these measures have some serious limitations for some applications. Both have the all-in-price of a bond in the denominator of their formulae. As a bond goes ex-coupon, therefore, and its all-in-price drops, so do duration and convexity show sudden increases. There are some portfolio managers who feel that to be given a target for such an erratic measure is nonsensical. A possible solution is to use a “clean” duration, where the clean price replaces the all-in price in the denominator.

However, the clean duration itself has limitations. Historically, it was customary to use duration (and convexity) to estimate quickly a portfolio’s sensitivity to parallel shifts in the yield curve, via the application of Taylor’s Theorem to the total portfolio value. One cannot apply the clean measures in the same way: they must be applied to a clean value, which is not generally available.

Even though this usage is now rare (with almost unlimited computer power it is simpler and more accurate to just re-value the portfolio), the appeal of the conventional measure lives on. Therefore, the duration and convexity measures of the indices will be the conventional, all-in ones.

In the light of the above, some simplifications will be taken in their calculation. The assumption will be made, in the calculation of duration and convexity according to the specifications of the Bond Pricing Formula, that bonds do not go ex-coupon, and hence are valued at all-in prices until their coupon payment day. The calculations will be made for the standard settlement day, with an adjustment to the valuation date. They will be performed daily on the portfolio after any re-basings for the day.

The virtue of these assumptions is that the portfolio can be treated as consisting only of its bond portion, and the ex-coupon portion can be safely ignored. Results will be exact as long as there are no re-basings between the real ex-coupon date and the coupon payment date; where there are re-basings, the percentage error will be negligible.

7.8.1 *Modified Duration*

The appropriate measure is the modified duration. Specifications can be found in the Bond Pricing Formula. As mentioned above, the calculation must assume that bonds do not go ex-coupon, and be for settlement on the standard settlement date.

Modified duration is given as follows:

$$dMod = \sum \left(N'_{i,t} \times P_{i,t} \times D_{i,t}\right) \times \frac{\left(dMod_{i,t} + \dfrac{H_{i,t}}{2\left(1 + Y_{i,t}/200\right)}\right)}{Z_t}$$

Where

$dMod_{i,t}$	is the modified duration of bond *i* for day *s*
$N'_{i,t}$	is the nominal amount of bond *i* in the portfolio, effective on or before the next trading day (*i*.e. after any Re-basing on day *t* has been applied)

Remaining Variables are as defined above.

7.8.2 *Convexity*

The convexity of the reference portfolio follows directly:

$$Conv = \sum \left(N'_{i,t} \times P_{i,t} \times D_{i,t}\right) \times \left(Conv_{i,t} + \frac{H_{i,t} \times dMod_{i,t}}{1 + Y_{i,t}/200} + \frac{H_{i,t} \times \left(2H_{i,t} + 1\right)}{4 \times \left(1 + Y_{i,t}/200\right)^2}\right) / Z_t$$

Where

$Conv_{i,t}$	is the convexity of bond *i* calculated for *t*'s settlement date, *s*, assuming it does not go ex

Remaining variables are as defined above.

7.8.3 *Application*

Modified Duration and Convexity can be used to estimate the change in value of the index for a given small parallel shift in the yield curve. From Taylor's theorem, we get:

$$\Delta I = I \times \left(-\Delta y \times dMod + \frac{1}{2}\Delta y^2 \times Conv\right)$$

Where

ΔI	Is the estimated change in the index
I	Is the current index value
Δy	Is the shift in yield expressed as a decimal (100 basis points is 0.01)

7.9 Precision and Rounding

All values are calculated and held to IEEE double precision (15 significant digits).

All-in and clean prices are rounded to 5 decimal places in accordance with the Bond Pricing Formula specifications.

Index values will be published rounded to three decimal places. This will allow calculation of returns to 2 decimal places (when expressed as percentages). A one basis point change in all yields to maturity will cause a change of about .05 in the index; the same change applied to the lowest market capitalisation constituent will not be observable in the third decimal place.

Durations will be published to two decimal places, and convexities to one.

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