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The PFaroe Asset Modelling Framework (Salmon)

Methodology

Version 1.04

Press release

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# Introduction

## Intention

This document describes the calculations, interpretation, and application of PFaroe’s Asset Modelling Framework. It has been written primarily for users of PFaroe who want to better understand how asset analytics are produced and the theory that has been developed to support these analytics.

For guidance concerning the definition of assets and usage of assets within PFaroe, please consult the online PFaroe *User Guide*, or contact Support.

## What is the PFaroe Asset Modelling Framework (Salmon)?

Salmon (Simple Asset Linear Modelling On Demand) is the technology behind PFaroe that models assets based on cashflows without the need for detailed security-specific information. The method is analogous to the *Alpha* technology underpinning cashflow-based liability analytics. The Salmon method supports:

* Point-in-time analytics
  + Asset valuations (including monthly and daily valuations)
  + Asset cashflows
  + Asset What if?
  + Curve exposure calculations
  + Market events
* Future-time analytics
  + Risk (VaR) including the Correlation What if?, Risk What if?, etc.
  + Asset and Liability Modelling (ALM)
    - Stochastic
    - Deterministic
  + Optimizer

The cashflows are associated with exposures to various equity markets and indices. The combination of cashflows and exposures allows the asset to be priced according to the macroeconomic environment prevailing in any given scenario specified in PFaroe.

## Why would I want to use Salmon?

### Fast and accurate analytics

The Salmon method was designed to meet our users’ need for fast and accurate asset and risk analytics. It creates efficiencies in two respects:

* First, the time taken to specify a fund in PFaroe is short (several minutes when the appropriate information is to-hand), and
* Second, the calculations for asset and risk are typically fast enough to support interactive online analysis in the PFaroe application.

### Reduced market data requirements

A further advantage of the Salmon technology is that it is relatively parsimonious in its market data requirements. The combination of shorter times and efforts required to commission and service funds, and fewer market data items, makes Salmon cheaper to operate for both RiskFirst and our clients.

### Flexibility to integrate external economic scenario generators

Finally, the Salmon asset engine also facilitates the integration of external economic scenario generators (ESGs).

### Alternatively: security-level modelled assets

Salmon is not appropriate for all situations, however, and our full-security-level modelling service remains an option for these specific needs. The table below summarises the two options available. Please take note that for future-time analytics, security-level-based funds are converted into a Salmon representation, as the security-modelling system cannot support stochastic or future-time projections.

|  |  |  |
| --- | --- | --- |
|  | **Security-level modelling** | **PFaroe Asset Modelling Framework (Salmon)** |
| **When** | Security details are available but sensitivities are not  Need to drill into/search fund contents at the security level in PFaroe  Complex, non-linear-payoff asset classes | Sensitivities available but security-level information is not  Sensitivities better describe the mandate/intent of the fund  Assets are typical fixed-income (bonds, swaps) and index-like investments |
| **Advantages** | Trading-level precision  Pricing from first principles | Fast: funds ready as soon as elementary market data (e.g. swap curves) are available and sensitivities input  Self-service (cheap)  Supports projections  Very fast (millisecond flexing time) |
| **Disadvantages** | Expensive to onboard and service (both personnel and market data voracious)  Slow monthly turnarounds  Can’t support projections  Slow (seconds to minutes flexing time) | Can’t support non-linear payoffs (optionality)  No finer granularity than annual cashflows |

## What are the inputs to Salmon?

A fund or security can be modelled in Salmon via the provision of sensitivities to a range of macroeconomic risk factors (interest rates, inflation, credit spreads, and equity markets. From these data, cashflows are derived accordingly.

Exposures to a variety of price indices are also provided.

These data are described by currency. The user may also specify a market value for the sensitivities and cashflows.

## What are the outputs from Salmon?

The cashflows and exposures can be priced according to a macroeconomic scenario. For instance, a scenario specifies a risk-free interest rate curve, credit spreads, inflation rates and equity price movements. The Salmon fund can then calculate its market value and expected cashflows (for instance, inflation-linked cashflows will change with inflation expectations) and report to PFaroe. Yield, spread and duration metrics are also calculated based on the expected cash flows.

When these calculations are quoted relative to the market conditions prevailing at the fund set-up date, the change in market value provides the data for PFaroe’s Asset *What if?* function. For future-time analytics based on stochastic scenario sets, the Salmon calculations are repeated to provide distributions for risk and return. In the ALM deterministic context, the user can describe the market conditions that will prevail at future timesteps, from which Salmon will calculate future cashflows, returns, and changes in price.

# The theory of Salmon

## Fixed income

Salmon uses standard fixed income results to infer a notional cashflow from the sensitivity of the unknown cashflow to risk free rates *r*. Starting from the fact that the present value of the notional cashflow *N* at duration *W* is:

when the risk-free rate is adjusted by 1 basis point upwards, the sensitivity *PV01* is:

This equation can be rearranged for *N*, the implied cashflow.

In general, sensitivities to inflation rates *IE01* can infer real notional cashflows, and Salmon assumes that all inflation-sensitive cashflows are also discount-rate sensitive. Similarly, credit-risky cashflows can be inferred given credit sensitivities *CR01* and specification of an initial spread *z*.

The inferred cashflow is weakly dependent on the assumed *z* assuming normal market conditions. Provided a reasonable specification for *z* is made (e.g. 100 basis points for an A-rated issuer), Salmon’s results will be realistic.

The real and credit-notional cashflows that are inferred all contribute to the overall *PV01.* Having inferred the real and credit-notional cashflows, the remaining *PV01* required to achieve the originally specified sensitivities is calculated and attributed to a purely risk-free, fixed cashflow:

For credit-risky sensitivities, we can assume .

At this point, we have a coherent set of real, credit-risky, and risk-free notional cashflows that will reproduce the original sensitivities exactly. In the case of the real notional cashflows, note that the quantity *N* is the uninflated cashflow. When the expected cashflows are to be calculated, these will be specified by *C*.

Salmon does not require nor does it adapt to knowledge of the type of instrument(s) or fund(s) which has (have) generated the sensitivities.

Salmon is agnostic of whether the sensitivities originated from a single instrument or a fund.

### Examples

The points below illustrate the relationships between the input sensitivities and the derived cashflows.

#### Credit bond

* First, IE01 = 0. There is no real inferred cashflow () and .
* As .
* We have
* And
* Therefore .

The result is that Salmon synthesises a single credit-risky cashflow

#### A fund composed of a corporate bond and an inflation-linked treasury (risk-free) bond

In general, all three cashflows are non-zero.

Further examples are provided later in the document.

### Multiple credit ratings

First, by rating, we really mean credit spread *z*. The extension to multiple credit ratings is straightforward as each rating can be considered independently.

Sovereign-issued debt can be assumed credit risky provided the reference risk-free curve is not itself a sovereign curve (e.g. Gilt, Treasury, Bund…)

### Tenors

The theoretical description above referred solely to bullet sensitivities at a duration *W*. The treatment can be extended in a straightforward manner to a term structure of sensitivities, provided that the sensitivities originate from non-overlapping stresses ("square waves"). In the case of overlapping stresses ("tents"), the interpretation of the sensitivities is made more complicated but is tractable in any case.

### Interpretation of the risk-free rate

In theory, we are free to pick any risk-free reference rate in Salmon. The credit sensitivities and assumed spreads must be consistent with the reference rate. At present, PFaroe only supports a swap curve as the risk free rate.

### Inflation-linked instruments

Inflation-linked instruments are assumed risk free but the credit risk can still be captured by the specification of the CR01s. What is missing is the complete interaction between inflation changes and credit spread changes – in this sense, credit-risky inflation-linked debt is effectively synthesised as a risk-free inflation instrument with a shorted credit default swap overlay. In any case, most inflation-linked bonds are backed by sovereign entities and attract relatively little credit risk.

### Convexity

Salmon naturally captures the effect of *convexity*, (i.e. that a 2 basis point shock is not just twice the result of a 1 basis point shock). Salmon’s calculations of the discount factors (or inflators) are exact; the binomial approximation is not used.

## Equities

By equities, we refer to the class of instruments whose cashflows are not explicitly known or specified. The description that follows equally applies to property/real estate modelled as a REIT (index), hedge funds, commodity indices etcetera.

## FX

Each fund or instrument is modelled in the economy of its local currency.

Aggregation of results from funds with varying local currencies is handled by separate calculations in PFaroe and is described elsewhere.

# Limitations to the Salmon method

### Non-linear payoffs

The Salmon method is designed for instruments with linear payoff functions. Note that this includes conventional bonds and that the phenomenon of convexity is naturally captured by Salmon. However, the following types of instruments, all of which have payoffs which depend non-linearly on some market variable (strike), cannot be well-modelled based on sensitivity and exposure information alone:

* Swaptions
* Equity index options
* Bonds with call options
* Fixed interest mortgages
* Limited price inflation (LPI) swaps

To address this limitation, RiskFirst has added a new modelling framework to price such assets outside the Salmon framework (known as project Philli explained at the end of this document).Floating cashflows using sensitivities

Interest-rate-sensitive cashflows (floating cashflows) cannot be resolved by the Salmon method when sensitivities are input. An interest rate shift to the instrument causes the floating cashflows to change with a corresponding cancelling change in the discount factor, so the overall sensitivity to interest rates is zero[[1]](#footnote-1). For this reason, a fixed-coupon bond and an interest rate swap look identical from the viewpoint of sensitivities because the swap’s floating leg is effectively invisible.

A number of options are provided to cope with these situations and are described further on.

### Floating rate notes with large rate shifts and credit shifts

A bullet [[2]](#footnote-2)floating rate note with cashflow *Q* at time *t* has market value:

for *r* the risk-free rate and *z* the credit spread. When either of these is flexed by an amount *δ*, the true change in market value is:

The Salmon method has inferred a credit cashflow and opposite risk-free cashflow so that only credit sensitivity results because the risk-free cashflow cancels out the interest rate sensitivity of the credit cashflow. In the case of a flex to the equivalent Salmon expressions, the change in market value is:

Both of these expressions are equal in a first-order expansion:

However, the higher order terms imply that the Salmon method is approximate for floating rate notes when conditions are flexed. When changes in credit spread or rates are of an order of 100 basis points (corresponding to stress outcomes from economic scenario generators), the typical error for a 10-year floating rate note is 5%.

### Annual cashflows

The implementation of the Salmon method does not presently accommodate sensitivities and cashflows specified finer than by annual tenors.

The cashflows are assumed to be paid at the end of the annual period with anniversaries on the valuation date.

# Point-in-time projections

## Inference of cashflows from sensitivities

### Inference from square wave stresses

Cashflows are inferred from the sensitivity specified at each tenor. If only summary information is available, whereby the sensitivities have been aggregated into *buckets,* a number of *inference methods* are available to convert the summary level information into a complete, tenor-by-tenor specification of sensitivities from which the cashflows are then inferred.

**The accuracy of the inferred cashflows is entirely driven by the granularity of the sensitivity information provided as an input.** The inference methods serve as a convenience to create a complete term structure of sensitivities (and, therefore, cashflows) based on assumptions. An accurate and appropriate term structure of cashflows will support the highest quality of analytics in PFaroe, particularly in scenarios where curve-based stresses are applied.

The inference methods are all specified for sensitivities generated by non-overlapping square wave stresses. By default, the size of this stress is +1 basis point.

| **Inference method** | **Description** | **Usage** |
| --- | --- | --- |
| Flat 01s | The sensitivity for the bucket is uniformly spread over each tenor of the bucket. Because the duration increases with each tenor in the bucket, the cashflows exhibit a downward sloping profile. | General purpose |
| Flat Zs (Legacy) | The sensitivity for the bucket is distributed over each tenor in the bucket such that the present value of the inferred uninflated cashflow at each tenor within that bucket is approximately even. | Legacy |
| Bullet 01s | The sensitivity is attributed 100% to the left-hand edge of the bucket and no redistribution is undertaken. | For modelling specific instruments such as swaps, or single bonds whose coupon structure is precisely known or zero (e.g. US STRIPS), or funds where the precise term structure of sensitivities is known. |

### Example I

In PFaroe’s *Fund Management* tool, users are required to specify sensitivities by maturity buckets. The bucket *left edge* is the earliest tenor of the bucket. Buckets must be non-overlapping and form a contiguous sequence. The left-edge tenor is inclusive to the bucket. Consider user inputs of the following form:

|  |  |  |
| --- | --- | --- |
| **Bucket left edge** | **Sensitivity** | **Width (Years)[[3]](#footnote-3)** |
| 1[[4]](#footnote-4) | 8 | 4 |
| 5 | 5 | 5 |
| 10 | 5 | 5 |
| 15 | … |  |

Each inference method will divide the sensitivity up as follows.

|  |  |  |  |
| --- | --- | --- | --- |
| **Tenor** | **Flat 01s** | **Flat Zs** | **Bullet 01s** |
| 0 | 0 | 0 | 0 |
| 1 | 2 | 0.80 | 8 |
| 2 | 2 | 1.60 | 0 |
| 3 | 2 | 2.40 | 0 |
| 4 | 2 | 3.20 | 0 |
| 5 | 1 | 0.71 | 5 |
| 6 | 1 | 0.86 | 0 |
| 7 | 1 | 1.00 | 0 |
| 8 | 1 | 1.14 | 0 |
| 9 | 1 | 1.29 | 0 |
| 10 | 1 | 0.83 | 5 |
| 11 | 1 | 0.92 | 0 |
| 12+ |

### Example II

Consider a longer series of sensitivities using the standard PFaroe bucketing scheme:

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Tenor left edge | 0 | 3 | 6 | 11 | 16 | 21 | 31 | 41 | 51 |
| PV01 | -3 | -5 | -2 | -11 | -14 | -11 | -5 | 0 | 0 |

### Inference of cashflows from non-square wave stresses

At the time of writing, only sensitivities generated from square wave stresses are supported.

## Determination of cash and floating legs

The value of the discounted, inferred visible cashflows known as the Implied Market Value (IMV) and the user's input market value for the sensitivities may differ either due to technicalities or because a fundamental structure cannot be resolved on sensitivity information alone. For example, an interest rate swap and a bond may have the same sensitivity profile, and will therefore infer the same cashflows. Yet, the market value of the swap (being typically close to zero) is evidently very different from that of the bond. The sensitivities do not resolve the existence of the corresponding floating leg of the swap.

The floating cashflows can therefore be specified by one of the following options:

1. **Inference of a *Cash on Account***: a single cash amount to correct the IMV to the market value input by the user. This amount accrues interest at LIBOR in projections and is never realised as a cashflow for investment in the ALM.
2. **Inference of floating legs**: a set of floating cashflows is specified whose shape is the same of the aggregation of the visible cashflows (risk free, inflation, credit). The cashflows are scaled such that their discounted market value corrects the IMV to the market value input by the user. This method requires the sum of visible cashflows to be non-zero. These cashflows are realised in ALM projections, just as the other types of cashflow are realised (when the fund is in run-off mode only, or, “Buy & Hold” in the PFaroe ALM terminology).

## Pricing

The cashflows are discounted using the respective discount rates to recover the hypothetical market value. For the fixed and real cashflows, the discount rate is the risk-free rate. The discount rate is the risky rate for the credit-risky cashflows. Floating cashflows are included in the price if they have been specified (through automatic inference or otherwise).

## Additional metrics

## The yield, spread and duration of a fund are calculated based on the inferred cash flows.

**Yield**

The yield of a fund is the value that discounts the visible cash flows to the implied market value (). In other words the yield balances the equation:

**Spread**

The spread in turn corresponds to the z-spread to the risk free spot curve that discount the visible cashflows to the implied market value. The relevant equation in this case is:

A single rating credit bond will therefore have a calculated spread that matches the user input spread for the CR01s.

**Duration**

Several duration measures are calculated for funds. The modified duration is based on the Macaulay duration and the yield of the fund with the following calculation:

Effective duration in turn is calculated as:

where , , and are the fund market value, and the market values when the risk free rate is stressed down or up by 1bps respectively. Effective credit duration is derived in a similar way but in turn stressing only the credit sensitive cash flows.

**Convexity**

Convexity of an asset demonstrates how the duration changes as the interest rates change. Convexity is calculated as:

**Limitations to the metrics calculations**

* Only effective duration, effective credit duration and convexity calculations are currently supported for notional assets.<http://docs.pfaroe.com/umbraco/umbraco.aspx>

## Typical fixed income modelling (including derivatives)

The table below summarises how typical fixed income asset classes would be effectively described by the PFaroe Asset Modelling Framework.

The input sensitivities (*x, y, z*) infer cashflows (*X, Y, Z*) **without explicit knowledge of the asset class**. Reuse of the same symbol for a given row in the table indicates the sensitivity or cashflows are of similar magnitude (e.g. a credit risky bond where CR01 = PV01).

The choice of *Cash on Account* or *Floating Leg* affects (a) the display of cashflows in the asset analytics and (b) generation of cashflows in ALM projections. The choice of *Transport method* affects how the cashflows change in time in ALM projections.

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Asset class** | **Sensitivities** | | | **Cashflows** | | | **Cash on Account or Floating Legs?** | **Transport method** | |
| Risk free rates | Inflation | Credit | Risk free | Real | Credit | Buy and Hold | Reinvestment |
| Fixed coupon bonds (risk free) | x |  |  | X |  |  | - | Yes | Yes |
| Fixed coupon bonds (credit risky, including government) | x |  | x |  |  | X | - | Yes | Yes |
| Inflation-linked bonds (risk free) |  | x |  |  | X |  | - | Yes | Yes |
| Inflation-linked bonds (credit risky) | x | x | x[[5]](#footnote-5) | -X | X | X | - | Yes | Yes |
| Floating rate notes (FRNs) |  |  | x | -X |  | X | Floating leg | Yes | Yes |
| Asset Backed Securities (ABS)[[6]](#footnote-6) | X |  | x |  |  | X | - | Yes | Yes |
| Credit Default Index (CDX) | y<<x[[7]](#footnote-7) |  | x | Y |  | X | Cash on Account | Yes | Yes |
| Credit Default Swaps (CDS)[[8]](#footnote-8) | y<<x |  | x | Y |  | X | Cash on Account | Yes | Yes |
| Interest rate swap | x |  |  | X |  |  | Floating leg inferred of approximately equal magnitude to fixed leg | Yes | No |
| Inflation swap |  | x |  | -X | X |  | - | Yes | No |
| Bond futures[[9]](#footnote-9) | x |  |  | X |  |  | Large negative Cash on Account position creates leverage | No | Yes |
| Total Return Swaps (TRS)[[10]](#footnote-10) | x | x | x | X | X | X | Floating legs create leverage | No | Yes |
| Repos | x | x | x | X | X | X | Floating legs create leverage | No | Yes |
| FX Forwards[[11]](#footnote-11),[[12]](#footnote-12) |  |  |  |  |  |  |  | No | Yes |
| Asset swaps |  |  | x | -X |  | X | Floating legs create leverage | Yes | No |
| Loans[[13]](#footnote-13) |  |  |  |  |  |  | Cash on Account | No | X |

# Future time projections

This section describes the behaviour of the PFaroe Asset Modelling Framework within PFaroe’s two forecasting modules:

* Risk (VaR)
* Asset and Liability Modelling (ALM)

## Timestep size

This document has focussed on the specification of annual sensitivities and cashflows. For demanding applications, finer granularities can be supported with modifications. Unless otherwise specified, the remainder of this document will assume that timesteps are annual.

## Pricing in future time

One of the main motivations for the PFaroe Asset Modelling Framework was to support pricing of assets in a future time context. The general idea is that a set of economic data (or market data) exists at future times and, once the Salmon cashflows are transported to the future time, these cashflows can be repriced at that time, following which any or all of the following quantities can be output:

* Market value
* Generated cashflows (arising from coupons, maturities, derivative cashflows, etc.)
* Return
* Remaining future cashflows

The economic data can be provided by:

* User inputs from the user interface:
  + The Asset *What If?* effectively defines a new set of economic data at *T0*
  + *Market Events* (instantaneous shocks at *T0*)
  + Deterministic (user-defined) scenarios in the *ALM*
* Stress testing modules (PRA and CCAR reporting in *ALM*)
* Economic Scenario Generator (ESG) scenarios
  + Sourced from RiskFirst’s support of the Conning GEMS ESG
  + From a client’s ESG

The process to price a fund at future time from these sources is:

1. **Retrieve the cashflows at *T0* and base market conditions**
2. **Calibration:** To correct, where necessary and required, the scenario economic data to be consistent at *T0* with the original market conditions
3. **Transport the cashflows to future time**: when the fund is defined the user selects from one of two transport methods which define how the fund ages in time
4. **Price the fund at future time** and return the results

## Calibration of initial conditions

For Assets projections in Risk and ALM, an initial condition adjustment is performed on the stochastic interest and inflation curves scenarios in order to accommodate the differences between the market curves as at valuation date and the initial *T0* curves used to generate the stochastic scenarios at each quarter.

Differences between the market curves used as at valuation date and the equivalent initial *T0* curves provided by an Economic Scenario Generator (ESG), may arise because:

* A shift of the curve has occurred in the market between the two dates
* There are errors in the calibration of the initial conditions (typically of order basis points) in the ESG
* No equivalent curve is available: e.g. the Salmon risk-free curve is taken to be swap-based while the ESG provides Treasuries only. This may also apply to the inflation curve construction (swap-derived inflation versus treasury-derived or BEIR curves)

We are interested in capturing the dynamics of the ESG and a prescription has been devised to account for these errors. However, it cannot guarantee that the resulting curves will be, for example, arbitrage-free. The only way to guarantee the original properties of the ESG is to calibrate the ESG exactly to the Salmon fund's initial conditions.

In details, a tenor-by-tenor shift is calculated at *T0* for each market forward curve as at valuation date with reference to the ESG counterpart *T0* curve. This vector of spreads is then added to each of the ESG's scenarios at all timesteps *TN*. The spread vector is shortened as the projection time proceeds by truncating the forward rates from the front end.

The focus of this section has been on correcting ESG data, but the concept of this spread calibration is also used in the stress-testing modules.

## Transport methods

The transport methods determine how a fund should age as projection time progresses.

### Buy and Hold (Run Off)

This should not be confused with the asset allocation strategy in ALM of “Buy and Hold”.

Assets are held until the last cashflow is realised. At each timestep, the cashflows move in by one year. Cashflows realised are held as cash on account and accrue interest at the risk-free rate (with the forward rate set in advance) unless taken out for trading in the ALM. The real notional cashflows are inflated according to realised inflation over the period.

#### Usage

This method is typically used for funds representing directly-held assets in turn hedging liability profiles. It may also apply to managed funds with fixed maturities. Example: *Fund Manager X’s 2045 UK Gilt Fund.*

#### Restrictions & Limitations

Buy and Hold produces unrealistic cashflows for bullet-based funds when the inferred, instantaneous, floating cash amount (CoA) is large relative to other flows. The Cash on Account is never realised and so the visible cashflows create a “lop-sided” cashflow stream in ALM projections. These funds should be modelled with the inferred floating legs option so as to generate a stream of expected floating cashflows that better offset the visible flows.

### Constant Reinvestment

Assets are held for a unit of time and the return is calculated. Any cashflow generated is re-invested in the fund at the next timestep, but with the cashflow profile of the fund identical to the original profile. While the return on the fund accounts for the inflation of the real notionals by realised inflation over the period, the reinvested cashflow profile does not include this effect.

In practice, the original cashflows are worth *q* at *T1*. Let the cashflows specified *T0* (brought inwards by one year and inflated where appropriate) be worth *p*. The cashflows for the original profile should then be increased by the ratio *p/q*.

#### Usage

This method is typically used for managed funds with constant duration. Example: *Fund Manager X’s 15-year AA Corporate Bond Fund.*

#### Restrictions & Limitations

Reinvestment is not permitted for funds whose market value of cashflows (including floating legs) is zero (e.g. interest rate swaps).

Note that the return is identical to the Buy and Hold method for the first timestep because the cashflow profiles are the same at the end of the first timestep. For subsequent timesteps, the results will diverge (e.g. the duration of funds using the Buy and Hold method decreases).

### Realised conditions

In addition to future spot curves for interest rates, inflation, and credit, any projection must also specify realised conditions. These define how interest is earned on the floating cash amount, and how inflation-linked cashflows should increase. Provision is made for the experienced (also known as *print* or *realised*) inflation rate to be different from the forecasted inflation rate. The user has control of this parameter in the ALM deterministic scenario specification and client-provided ESGs may generally output these data directly.

## Value at Risk (VaR) and ALM

We now examine how the projections can be exercised by a stochastic scenario provider. Usually, and in PFaroe, this takes the form of an Economic Scenario Generator (ESG), but historical market data could be used. The discussion will concentrate on the ESG embedded in PFaroe, namely the GEMS ESG provided by Conning. However, provision of scenario data by a client's ESG is supported.

In the PFaroe risk module, a configuration can be made to stress Salmon funds one year into the future with scenarios from an Economic Scenario Generator (ESG). The procedure is:

* The fund is transported to one year in the future using simulated curves and stress from the ESG including any "realised conditions", using the same functions presented in prior sections.
* The stochastic market value of the fund is therefore known. According to the configured transport method, any realised cashflows are either added to the value of the fund as cash (buy and hold) or reinvested (revestment) but as we have already witnessed the choice of transport method does not affect the value of the fund after only one year of projection.

### Risk attribution

The Salmon fund is then selectively stressed by the interest rate, inflation, and credit spread environment at the future time to calculate stochastic scenarios for PFaroe's risk attribution:

* For the calculation of interest-rate risk, the Salmon fund is revalued at the future timestep using the scenario-specific, risk-free interest rate curve and the average inflation. The credit cashflows are valued using a credit curve composed of the scenario-specific, risk-free rate curve and the average credit spread.
* For the calculation of inflation risk, the Salmon fund is revalued at the future timestep using the scenario-specific inflation curve (and realised inflation) and the average interest rate and credit curves.
* In general, the scenarios for any risk factor are calculated by revaluing the Salmon fund while holding all other risk factors at the *T*1 average (median).

The scenarios by risk factor are then aggregated with the results for other funds and the VaR is calculated.

#### Origin scenario

The risk attribution treatment can be generalised for use by other VaR definitions by calculating the deltas relative to the *origin scenario*:

* In the RiskFirst GEMS Monte Carlo VaR 1Y method, the origin scenario applies the average economic stresses at *T*1. The VaR (in aggregate and by each risk factor) is quoted relative to the average result at *T*1
* In historical VaR, the origin scenario is the *T*0 scenario and the VaR is quoted relative to the *T*0 position. No transport method is employed.
* Some VaR calculations define the origin scenario as the economic conditions prevailing at *T*0.

In any VaR calculation, there is a single origin scenario and *n* stress scenarios.

# Non-Linear Asset Modelling Framework (Philli)

## Introduction

The Salmon method has been designed for instruments with linear payoff functions. Note that this includes fixed income instruments, and that the phenomenon of convexity in bonds is naturally captured by Salmon.

However, options, which have payoffs which depend non-linearly on some underlying market variable, cannot be properly modelled based on sensitivity and exposure information alone:

Given the materiality and importance of nonlinear assets, RiskFirst has added a new modelling framework to price such assets outside Salmon framework (known as project Philli).

Philli complements Salmon’s pricing and risk management functionality by adding support for options.

### Coverage of Philli

1. Equity options, Equity index options, Swaptions.
2. Options that are not covered by Philli: LPI swaps, non-core currency equity index options, CDS index options, all other options excluding 1. above.

## What is an Option?

An option is a contract that gives the buyer the right, but not the obligation, to buy or sell a particular asset at some fixed price (called strike), on or before a specified date.

The seller of the option, conversely, assumes an obligation in respect of the underlying asset upon which the option has been traded.

## Terminology

* A call option is an option to buy an asset (the underlying) for a specified price (the strike or exercise price), on or before a specified date.
* A put option is an option to sell an asset for a specified price on or before a specified date, demanding the pre-agreed sum in exchange.

## Option Pricing Model

The purpose of an option pricing model is to give information on how the value (price, or premium) of an option behaves under different market conditions.

Philli uses the classic Black & Scholes options pricing formula:

Price of a Call Option = S N(d1) – E N(d2) e-rt

Price of a Put Option = E N(-d2) e-rt - S N(-d1)

Where

* d1 = [ ln(S/E) + R (s2 / 2) t ] / [ s √t ]
* d2 = d1 - s √t
* S = underlying price
* N = cumulative normal density function
* e-rt = continuously compounded rate of interest
* E = exercise price of option (also called strike)
* R = risk free rate of interest
* s2 = variance of the rate of return
* t = time to expiration of the option
* s = square root of the variance (volatility)

### Backward Compatibility

Prior to Salmon and Philli, Risk First’s legacy pricing framework (Legacy) for non-linear assets (GEMS) also used the Black-Scholes methodology.

As such there is no modelling differences between Legacy and Philli in the treatment of non-linear assets.

# Frequently Asked Questions

## Sensitivities

**I want to create a fund from sensitivities but I only have parallel shift metrics. How can I proceed?**

Without more information, the quality of generated cashflows and subsequent analytics will be poor. There are no inference methods available that can create a “typical” sensitivity profile.

If the sensitivity pertains to a single instrument – especially bullet instruments (swaps, zero-coupon bonds) – then the sensitivity can be precisely specified at the maturity date of the instrument with the *Bullet 01s* inference method.

If the sensitivity has been calculated from a mixture of instruments, holdings, etc., then further analysis will be necessary.

**How should the credit spread for each rating of credit sensitivities be set?**

The credit spread should represent the single parallel shift (z spread) to the risk free spot curve that will discount the inferred cashflows to a market value.

The inferred cashflows are weakly dependent on the credit yield for non-defaulted bonds. Higher spreads will imply higher cashflows to be consistent with the same sensitivity.

If the sensitivities have been calculated from a pool of bonds, we suggest using the market-value-weighted z spread.

**How many buckets should I specify?**

As many as there are buckets of sensitivities in the source data for the sensitivities. If tenor-by-tenor sensitivities are available, these should be input directly.

The inference methods are a convenience for generating a full term structure of cashflows when a full term structure of sensitivities is not available. However, they imply a set of assumptions which, if they *can* be avoided, *should* be avoided by using the original data.

## Cashflows

**Why does the cashflow profile for Fund X appear to have a sloping appearance?**

If the sensitivities were originally input at a tenor-by-tenor level, then this would indicate that either the fund truly does have that cashflow profile or the system that generated the sensitivities has introduced some artefacts.

More commonly, when sensitivities are input as buckets spanning multiple years, an inference method has been chosen that is not best for creating flat cashflows.

**Are cashflows at tenor 0 allowed or supported?**

No. If a bucket is specified with tenor left edge of 0, then the next bucket must not have a left edge of 1.

When the discounted market value of the inferred cashflows is different from the user’s input market value, and the user chooses to use ‘*Cash On Account*’ as the balancing item, this cash amount is held in perpetuity and accrues interest at LIBOR.

**When are cashflows assumed paid?**

All Salmon cashflow timing is end of year with anniversaries on the valuation date.

**Does the choice of ‘Cash On Account’ and ‘Floating Cash flows’ affect the spread, yield, and duration my fund?**

These fund metrics are calculated based on the visible cash flows of the fund, not taking into account the balancing item. As the choice between ‘Cash On Account’ and ‘Floating Cash Flows’ define the treatment of this balancing item, it does not affect the metrics.

**Can I define a Fund of Funds where the buckets of sensitivities used to define the constituent funds are different?**

Yes. Once the tenor-by-tenor cashflows have been inferred, funds can be freely combined.

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1. Exactly true for cases where the credit spread is zero. This is because the product of the discount factor and floating rate multiplier is unity. [↑](#footnote-ref-1)
2. A “bullet” bond consists of a single cashflow at maturity. It has zero coupons. [↑](#footnote-ref-2)
3. Users do not explicitly input the width; this is calculated from the sequence of bucket left edges and shown in this table for illustration [↑](#footnote-ref-3)
4. If the first bucket’s left edge is 0, it is internally treated as being 1 as no cashflow can be inferred at tenor 0; unless the next bucket has a left edge of 1, in which case an error is generated. [↑](#footnote-ref-4)
5. Credit risk for inflation-linked bonds is modelled as an overlay of credit-risky, non-inflation-linked cashflows [↑](#footnote-ref-5)
6. Inferred notionals and cashflows reflect notionals already paid down [↑](#footnote-ref-6)
7. CDS, CDX show a very small amount of interest rate sensitivity [↑](#footnote-ref-7)
8. Effectively equivalent to CDX treatment; no specific payouts on individual default events are accommodated [↑](#footnote-ref-8)
9. Rolling contracts assumed [↑](#footnote-ref-9)
10. Rolling contracts assumed [↑](#footnote-ref-10)
11. Long/short cash positions in two economies [↑](#footnote-ref-11)
12. Rolling contracts assumed [↑](#footnote-ref-12)
13. Rolling contracts assumed [↑](#footnote-ref-13)