MOODY'S

Assets in PFaroe

Table of Contents

1 Asset Modelling in PFaroe

This guide covers the creation of asset valuations in PFaroe and the methodology underlying the asset valuation engines used.

Some basic concepts and terminology are used throughout this guide. These include:

- Allocation**:** This defines an asset portfolio at a date, in terms of holdings in specific **Funds**. It may represent a pension plan's actual allocation, or an alternative allocation that is under consideration, or a potential allocation that may be selected in a stochastic ALM projection at a future time step.
- Fund**:** Most widely used base unit of asset modelling within PFaroe. It defines specific sensitivities to changes in market conditions, both at a point in time, and in a future deterministic or stochastic projection and can also specify a cashflow profile. Different types of funds are used for different purposes.
    - **Benchmark Fund:** These are a suite of PFaroe Benchmark funds maintained by Moody's, reflecting the properties of all major asset classes. This provides users with a straightforward way of capturing the key characteristics of any pension plan’s asset portfolio without needing to create custom funds.
    - **Custom Fund:** These are funds defined by users. They may be restricted to specific clients or shared, and are available at a user-defined date range.
- Fund Manager**:** This is the tool used to create and manage **Funds**
- Holdings**:** Where assets are loaded in PFaroe at a position level (ISIN/CUSIP/Term sheet) these are referred to as Holdings. **Funds** are generally a representation of a group of **Holdings**.
- Payment Schedule**:** This is a store of cashflow information. It is used to roll forward assets and liabilities consistently.
- **Risk Factors:** This is used within **Funds** to associate the fund to a given stress applied by the user or provided by the economic scenarios from a scenario generator. Eg A fund could have the risk factor of 'Global equities' and will be affected if global equities is stressed by a user in PFaroe DB; the returns of the **Fund** will be driven by the global equities returns in ALM.

Each of these concepts are discussed in detail in this guide.

2 Allocations In PFaroe

An **Allocation** in PFaroe effectively defines an asset portfolio in terms of holdings in specific Funds.

It may represent a pension plan's actual allocation, or an alternative allocation that is under consideration, or a potential allocation that may be selected in a stochastic ALM projection at a future time step.

An **Allocation** at a specific date can be rolled forward, in conjunction with cashflow information in the Payment Schedule, to determine an asset portfolio at a future date.

Allocations are used to create month-end asset valuations.

You can create, edit, review and publish **Allocations** within Fund Allocations.

Allocations can also be created automatically from an **Asset Feed**. This requires an asset feed to be configured between PFaroe and the source of the data (usually the Plan's custodian), and fund mappings to be configured and maintained by the user.

Allocations can be used across PFaroe, including in What if? functionality, ALM and Optimizer.

2.1 Defining Allocations

To access the Allocations module click on **Setup > Assets > Allocations**.

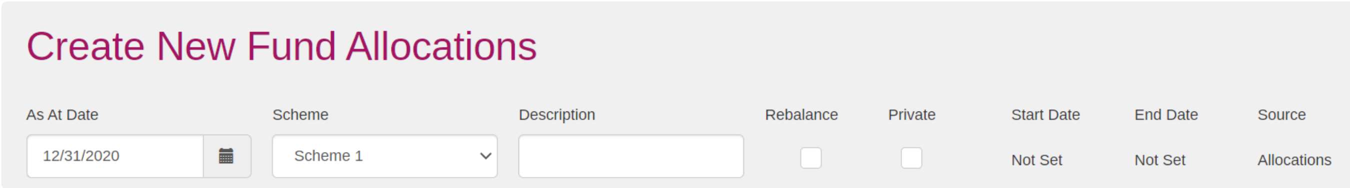
This shows a list of available allocations.

- The Published tab shows the Allocations which have been used to generate analytics
- The Saved tab shows alternate saved allocations available for use - for example, as a potential allocation at future timesteps in an ALM projection

Where additional strategies or breakdowns have been defined, there will be an additional dropdown menu to filter the list.

2.1.1 Adding a new Allocation

To enter a new asset allocation from the Allocations Module, click **Create new**.



On the Create New Fund Allocations page:

- Select the **As At Date**
- Select the Plan or Scheme
- Select the strategy or breakdown (if applicable)
- Enter a **Description**
    - **Tip** The description is not required but may help you manage a long list of allocations across multiple plans and dates
- Check the **Rebalance** box if required. When rolling forward an allocation, this will rebalance non-derivative assets at the end of each month using the original percentage allocation.
- Check the **Private** box to restrict the allocation to your individual user account

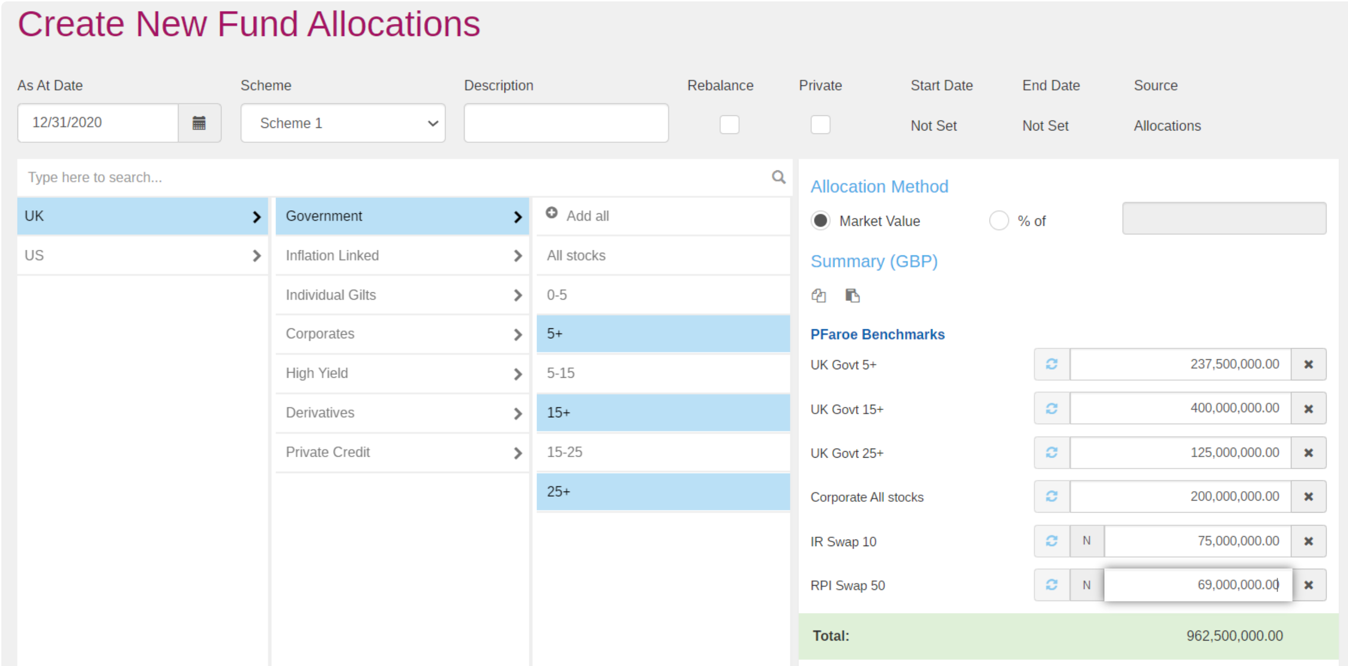
Fund Picker

The Fund Picker shows a list of Funds, broken down into categories. This will include **Benchmark Funds** and any **Custom Funds** to which you have access.

To add a Fund to the allocation, click the Fund name.

To quickly add all available Funds in a category, click the **Add all** button.

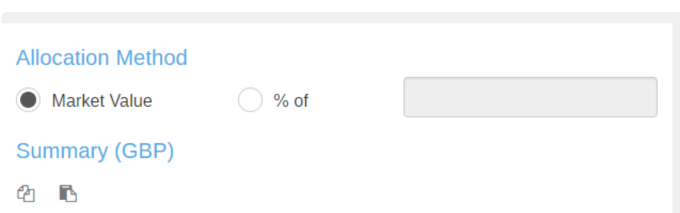
Funds can be found by navigating through the lists of categories, or using the Search feature.



Allocation method

Select one of the following options for specifying the allocation method:

- **MV:** Enter the market value in each Fund in the base currency. The sum of the values entered is shown in the Total box.
- **% of**: Enter a total market value, and enter a percentage allocation to each Fund.
  - **Note** The percentage allocation must add up to 100.00%. Use the  button to quickly allocate any remaining balance to an available Fund.



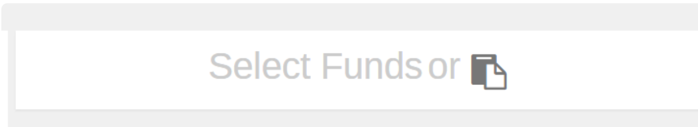
Copy and Paste

You can use the copy and paste feature to create allocations in a separate tool, including Excel. This can help users manage allocations across multiple clients efficiently.

Click the copy button  to copy the selected funds and amounts on to your clipboard. You can then paste this into an external application.

Click the paste button to paste an allocation from your clipboard. PFaroe will validate the format and values of the data being pasted.

The paste option is also available before any funds have been picked.

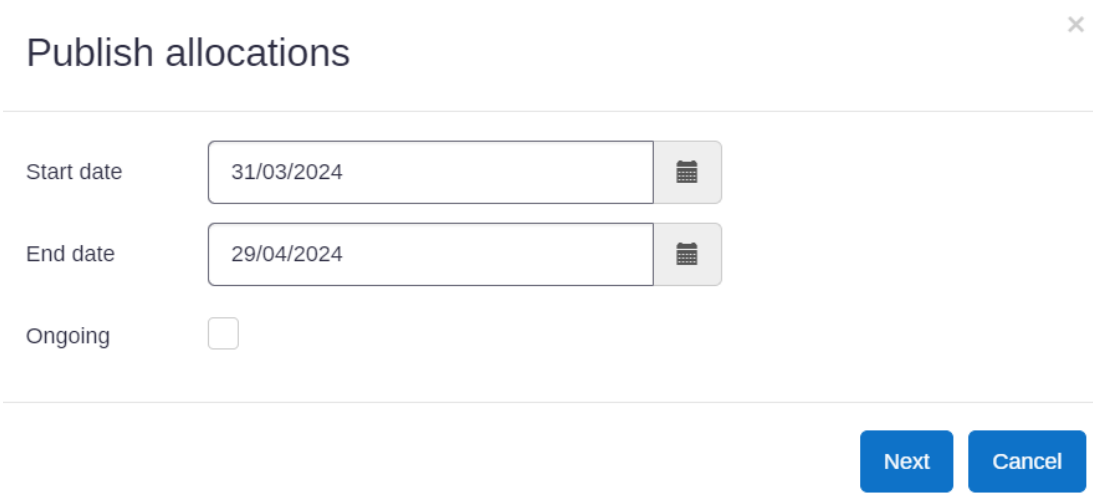


Publish Allocation

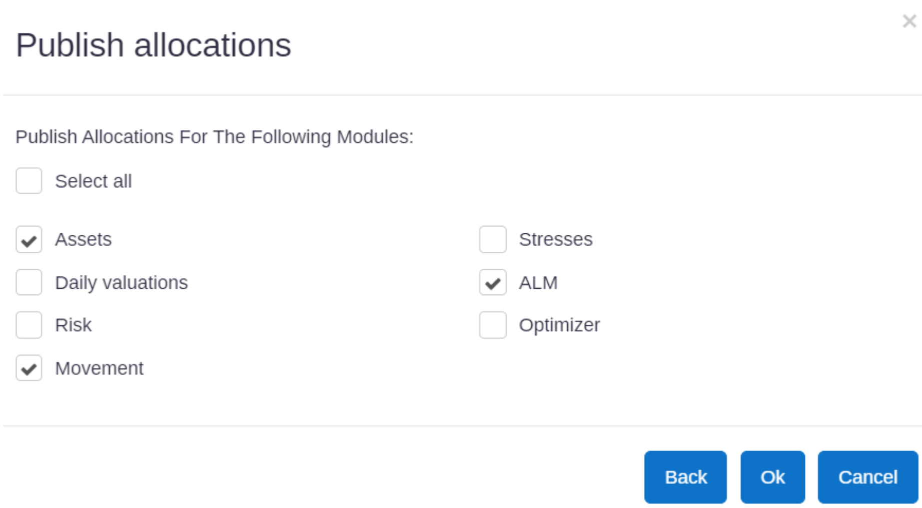
Click **Publish** to publish the allocation.

> **Warning!** Before publishing an allocation after the As At Date, you should review the **Payment Schedule**. This is discussed in the Asset roll forward methodology section.

- Enter the **Start date**. This can be any date on or after the **As At Date**.
- Enter the **End date**, or check **Ongoing** to keep using at future dates
- Click **Next**



- Select which modules the allocation should be published for.
  - **Tip** You can use different allocations for different purposes. For example, one allocation may be set up to ensure daily tracking is accurate, and another may be set up for ALM calculations.



Save Allocation

Click **Save** to save an allocation without publishing it.

This may be used in PFaroe in various ways, including testing asset allocations using the Risk What if? functionality, or as part of a trigger strategy in ALM.

2.1.2 Editing Allocations

Click on the **Edit** button next to an allocation to edit it.

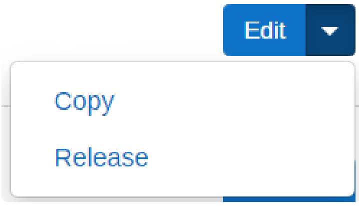
You can then:

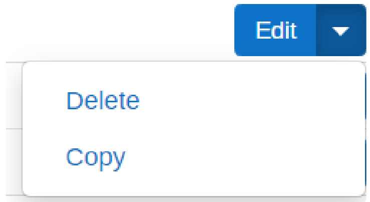
- Edit the list of funds and values in the same way as described above
- Click **Update** to republish the allocation. You can:
    - Reflect any changes in values
    - Change the dates and modules where the allocation is published

Alternatively, click **Unpublish** to remove any analytics using the allocation. The allocation will then appear under the Saved tab.

2.1.3 Managing Allocations

Several further options are available through the button next to each allocation. Different options are displayed depending on the allocation.





- Click **Release** to release a Published allocation. A Released allocation can not be edited.
- Click **Unrelease** to return an allocation to Pending status (and allow editing).
- Click **Copy** to create a new allocation, using the selected allocation as a starting point
- Click **Delete** to delete an allocation. This is not available for Published allocations.
    - **Note** To delete a Published allocation it must first be **Unreleased** (if required) and then **Unpublished** (as described above). The allocation will then appear under the Saved tab.

Click **Show Publish Locations** to see which modules have been populated using each allocation.

2.1.4 Create Multiple Allocations

This functionality allows allocations to be added quickly and efficiently.

To add multiple allocations at the same time:

- Click **Create New > Create Multiple**
- Click **Create Excel Template**
    - Select a list of Plan names, dates, and the number of allocations required
    - Create a list of funds using the Fund Picker (as described above)
    - Click **Download**
- Populate the downloaded template. The inputs are as described above.
- Click **Paste From Template**
- Copy and paste the grey area from the template
    - PFaroe will validate the inputs and provide feedback on any errors
- Click **Upload**

If you already have a template in the required format, you can proceed directly to the upload step. To do this:

- Click **Create New > Create Multiple**
- Click **Paste From Existing Template**
- Copy and paste the grey area from the template
    - PFaroe will validate the inputs and provide feedback on any errors
- Click **Upload**

2.1.5 Daily Valuations

Daily Valuations can be published as described above.

To republish daily valuations:

- Click **Daily Valuations**
- Select a Plan
- Select a **Start Date** and **End Date**
- Click **Ok** to rerun daily valuations for the selected plan and date range

This may be required if the **Payment Schedule** has been updated.

2.1.6 Child Headers

Child Headers are automatically-generated allocations which reflect the rolled forward allocation at each month end. They are a technical feature intended to improve performance and stability of PFaroe's asset analytics and are not intended for general usage.

To see the list of Child Headers produced from an allocation, click on the button next to the allocation name.

Child Headers can only be viewed (not edited, copied or published).

2.2 Allocations elsewhere in PFaroe

You can use saved asset allocations and create new allocations in different areas of PFaroe:

- In **Curve Exposure** analysis under **Combined > Curve Exposure**
- In the **What if?** functionality in the Analytics module, under **Combined > What if?**, **Assets > What if?** or **Risk > What if?**
- In **ALM** projections
- Using the **Optimizer**

This works in the same way across PFaroe modules, using these buttons:

2.2.1 Creating allocations

In each case, the allocation is defined using the Fund Picker. This works in the same way as in the **Fund Allocations**.

Click the **Save Allocation** button and then:

- Select **Market Value** to save the allocation for the current plan and date, in market value terms

- Select **Percentage** to save the allocation in percentage terms. In this case it can be shared across Plans and used across any date.
- Enter a **Description**
- Choose whether to make the allocation **Shared** across all users, or **Private**

2.2.2 Opening allocations

Click the **Open Allocation** button to select from an available saved allocation. These may be restricted to the selected Plan and date.

This will overwrite the allocation for the current analysis.

2.3 Asset roll forward methodology

2.3.1 Allocation roll forward

PFaroe will calculate the assets at any date after the As At Date of the allocation by:

- Rolling forward each fund, using the methodology described below
- Allowing for cashflows in and out of the Plan, as specified in the **Payment Schedule**. The net cashflows are reflected in the Cash fund.

2.3.2 Fund roll forward

The roll forward methodology for each fund is defined using Fund Manager.

Market Value Funds

The majority of assets use a Market Value approach, where a fund is linked to a specific market index.

In terms of **Benchmark Funds**, this includes:

- Fixed Income
- Equity
- Real Estate
- Alternatives

To determine the closing market value on day t, the closing market value on day t-1 is increased by the percentage change in the specified market index during day t:

$$MV_t = MV_{t-1} \frac{Index_t}{Index_{t-1}}$$

Notional Funds

Some Funds are defined using a Notional approach. In terms of **Benchmark Funds**, this includes:

- Interest Rate Swaps
- Inflation Swaps

To determine the closing market value on day *t*, the Notional amount at the allocation date, *AD*, is multiplied by the percentage change in the specified index value between the allocation date and day *t*.

$$MV_t = Notional_{AD}(\frac{Index_t}{Index_{AD}} - 1)$$

Cash

The roll forward for cash holdings reflects both interest accruals, any cash inflows (employee and employer contributions) and any cash outflows (benefit payments and expenses), as specified in the **Payment Schedule**.

The roll-forward is calculated on a daily basis, capturing the day that any cashflow is paid.

$$Cash_t = Cash_{t-1} * (1 + i)^{1/365} + Net\ cashflows_t$$

The daily interest rate *i* is standardized for each currency.

The Payment Schedule includes various different types of cashflows, which can vary by client. In general these are entered as positive values.

Net cashflows are calculated by:

- Summing the contributions (employee, employer and other types)
- Subtracting benefit payments and expenses
- Other cashflow types may be added or subtracted, depending on their type

Payment Schedules may also be set up for buy-ins and longevity swaps. In general these should only contain benefit payments, but other payment types will also be used in the calculations.

Total benefits are calculated by:

- Summing the benefit payments from the liabilities and any longevity swap fixed legs
- Subtracting the benefit payments from any buy-ins and longevity swap floating legs

Fund of Funds

Fund of Funds can follow two distinct approaches, specified in Fund Manager:

- Rollforward using constituent Funds. The value will be calculated each day by rolling forward each fund (based on its own rollforward approach) and summing.

- Rollforward using specific market index. The value will be calculated each day using the Market Value approach described above.

3 Funds in PFaroe

Funds are the most widely used base unit of asset modelling within PFaroe.

They define specific sensitivities to changes in market conditions, both at a point in time, and in a future deterministic or stochastic projection and may define cashflows from the fund. The Fund modelling engine is discussed in detail here.

Funds are referenced by **Allocations** to specify a Plan's asset holdings at a specified point in time.

Fund Manager is the tool where you can define **Custom Funds**, and is used by Moody's to maintain **Benchmark Funds**.

There are several types of Funds, all created using **Fund Manager**:

- **Fund of Funds ("FoF")**: Aggregations of existing funds. The weights to each fund can be customised.
- **Leveraged**: A Fund of Funds with leverage bands. The fund returns to the original leverage ratio if a leverage band is hit in ALM.
- **Sensitivities and Exposures**: These funds are defined by their sensitivities to interest rates, inflation rates, credit yields, and by effective notional exposures to a range of market indices.
- **Risk Factors with cashflows:** These funds have exposure to risk factors and associated cashflows. The associated cashflows are not interest, inflation or credit sensitive but can be defined to grow with fund returns.

The methodology underlying the modelling of these funds is discussed in detail in this guide.

PFaroe Benchmark Funds are a suite of funds maintained by Moody's, reflecting the range of asset classes used by institutional investors. This provides users with a straightforward way of capturing the key characteristics of any pension plan’s asset portfolio without needing to create custom funds.

Custom Funds are funds defined by users. They may be restricted to specific clients or shared, and are available for a user-defined date range.

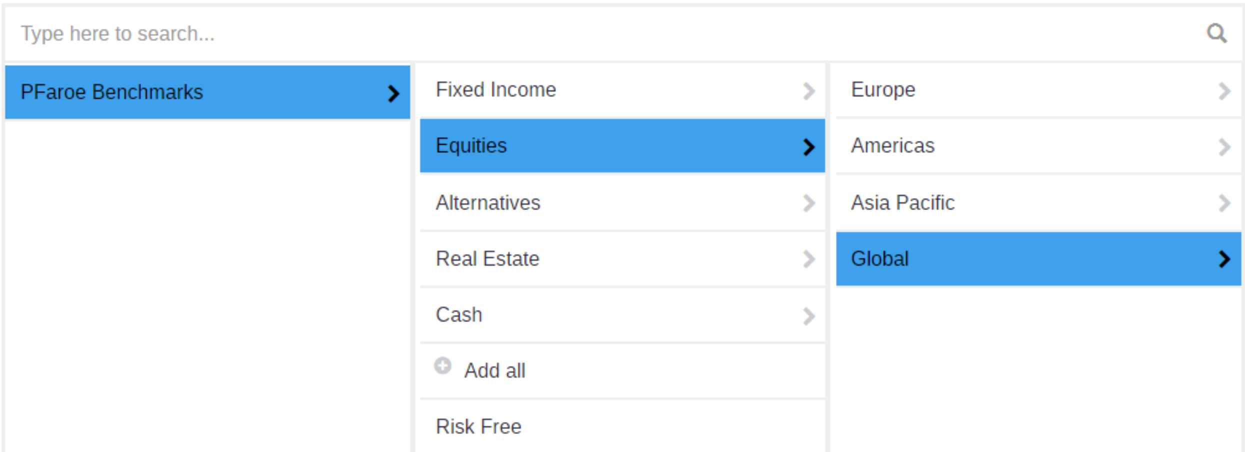
3.1 Benchmark Funds

Moody's Analytics maintain a suite of PFaroe Benchmark funds, reflecting the range of asset classes used by institutional investors. This provides users with a straightforward way of capturing the key characteristics of any pension plan’s asset portfolio without needing to create custom funds.

The Benchmark funds available will vary through time, based on user feedback and availability of data.

3.1.1 Using Benchmark Funds

They appear in the Fund Picker under **PFaroe Benchmarks**, broken down by asset class and geography.



They can be used directly in **Allocations**, or when creating a custom Fund of Funds.

3.1.2 Modelling of Benchmark Funds

Benchmark Funds are defined using Fund Manager, in the same way as custom funds. Typically they are updated monthly.

A document setting out the key properties of each of these benchmark funds each month is available in PFaroe via **Analytics > Reporting > Downloads**.

3.1.3 Notes on specific Benchmark Funds

The PFaroe Benchmark funds are intended to be useful for modelling typical pension fund assets, and details of the modelling are available through PFaroe, as described above.

Some implications and comments are set out below.

- **Individual Gilts**: This includes all UK gilts with at least one year until maturity
- **High Yield**: This includes Global, US and European high yield credit
    - In general, although they are shown under **Fixed Income** in the hierarchy, **High Yield** funds do not reflect sensitivities to interest rates, inflation and credit spreads. They will not contribute to sensitivities in the Curve Exposure module.
    - Some US high yield bond funds however will reflect sensitivities like other Fixed Income assets. These are available under **Fixed Income > US > High Yield > IR**

- **Derivatives:** There are a variety of fixed income derivatives available. These are generally allocated to using notional values rather than market values. Notional value reflects the uninflated leg of the swap at time 0. Funds reflect a new trade as at the effective date so market values are zero.
    - For interest rate swaps, positive notional values equate to pay floating/receive fixed (and negative notional values equate to pay fixed/receive floating)
    - For inflation swaps, positive notional values equate to pay fixed/receive inflation (and negative notional values equate to pay inflation/receive fixed)
    - Given the OTC nature of many derivatives, modelling existing positions will generally require approximations to be made by the user.
- **Equities:** a range of currency-hedged and unhedged equity funds are available

3.2 Fund Manager

Fund Manager is the tool which allows users to create **Custom Funds** for use across PFaroe.

It is accessible through https://funds.pfaroe.com

3.2.1 Basic Concepts

A **Fund** is a "shell" containing some basic information, such as **Fund Type**, currency, and date range, how the fund is rolled-forwarded for daily valuations.

A **Fund Update** contains the detailed information required to model the fund. Fund Updates **should typically be made each month** for more complex funds to ensure modelling remains appropriate (without this update fixed income funds (for example) will gradually get less and less representative).

There are several **Fund Types** which are available to reflect the characteristics of different asset in PFaroe DB analytics:

- A **Sensitivities & Exposures** fund is the most general fund type, used for listed equity, fixed income and simplistic allocations to alternatives or private assets. It is defined through:
    - exposure to different risk factors (generally equity-like); or
    - sensitivity data (PV01, CR01, IE01); or
    - expected cashflows
- A **Fund of Funds** is defined by allocations into one or more existing funds (whether **Benchmark Funds** or **Custom Funds**). It can be used to represent actual Fund-of-funds or to 'white label' other existing funds.
- A **Risk Factors with Cashflows** fund is a special type of Sensitivities & Exposures fund intended to represent investments which have relatively well known cashflows which aren't viewed to directly drive the value of the fund. For example a listed equity fund distributing dividends or a private fund returning capital to investors. It is defined through:
    - an exposure to a risk factors which will primarily determine changes in market value

  - associated Cashflows which have no interest, inflation or credit sensitivity, but can grow or reduce with fund returns

- A **Leveraged fund** is a **Fund of Funds** with the addition of leverage bands designed to model pooled LDI funds. The bands control the fund's leverage ratio.
- An **Equity Index Option** fund allows modelling of equity index options.

3.2.2 Funds

A **Fund** is a "shell" defining key features of a Fund in PFaroe.

There are several different **Fund Types**. These work in different ways and have different inputs.

Details of the methodology underlying each fund is set out in the Fund Modelling Methodology section. This includes more discussion of the inputs set out below.

Once a Fund has been created, a **Fund Update** must be added.

Fund Management

The Fund Management screen lists all funds to which you have access.

From this screen you can:

- Create a new fund
- Edit existing funds
- Delete existing funds
- Add, view and edit **Fund Updates** for a fund by clicking the button
- Update multiple funds efficiently

Creating a Fund

To add a new fund, click **Create Fund**. This will lead you through the steps below.

- **Tip** Hovering over a term often displays a helpful tooltip as a reminder

Step 1: Fund details

These inputs are required for all fund types:

- **Name:** This is how the fund will appear in the Assets module.
  - **Note** The name in the Fund Picker may be different; see Step 2
- **Type:** Choose one of the available **Fund Types**

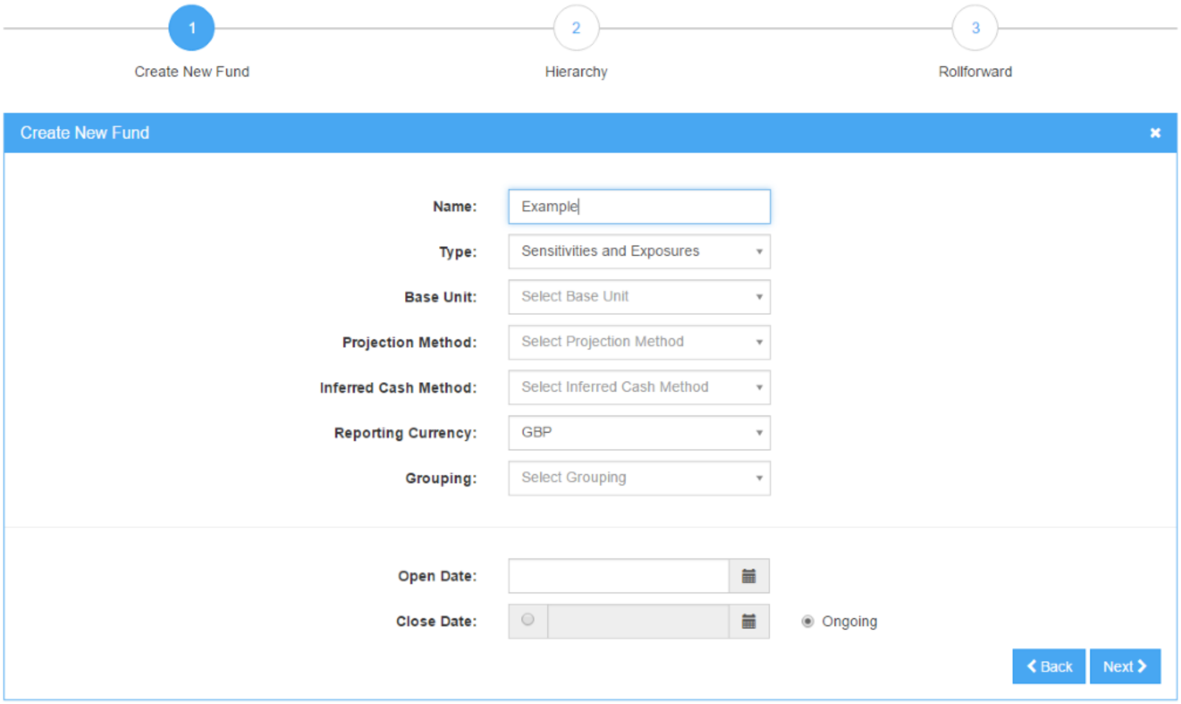
- **Base Unit:** Choose from
  - **Market Value:** Allocations are made to the fund in terms of market value amounts. This is generally appropriate for most assets (except derivatives).
  - **Notional:** Allocations are made to the fund in terms of a notional currency amount. This is generally appropriate for derivatives.
- **Reporting Currency**
  - **Note** This may be pre-selected if only one is available
- **Grouping:** The Grouping of a fund determines how it will be aggregated into an asset class category; see the Fund Grouping section below
- **Open Date:** This should generally be a month end date
- **Close Date:** This would generally be set to **Ongoing**, unless the fund is only required over a specified date range

This input is required for a Fund of Funds:

- **Rebalance** determines whether the fund adjusts over time to maintain the defined allocation

These inputs are required for Sensitivities & Exposures funds:

- **Projection Method** defines how the fund's returns are treated.
  - **Buy and Hold:** Assets are held until the last cashflow is realised. The duration of the fund will shorten over a projection.
    - **Tip** This is not the same as the *Buy and Hold* allocation strategy in the ALM module
  - **Reinvestment:** Assets are held for a unit of time and the return is calculated. The fund's duration stays constant through time.
- **Inferred Cash Method** determines how the difference between user defined and implied market values is treated.
  - **Cash on Account:** The difference is captured by a single cash amount. This is intended to capture small model differences and is generally expected to be small.
  - **Floating Cashflow:** The difference between user defined market value and implied market value is captured by cashflows that match the cashflow profile of the sensitivities. This is typically used to model derivatives with a floating leg.



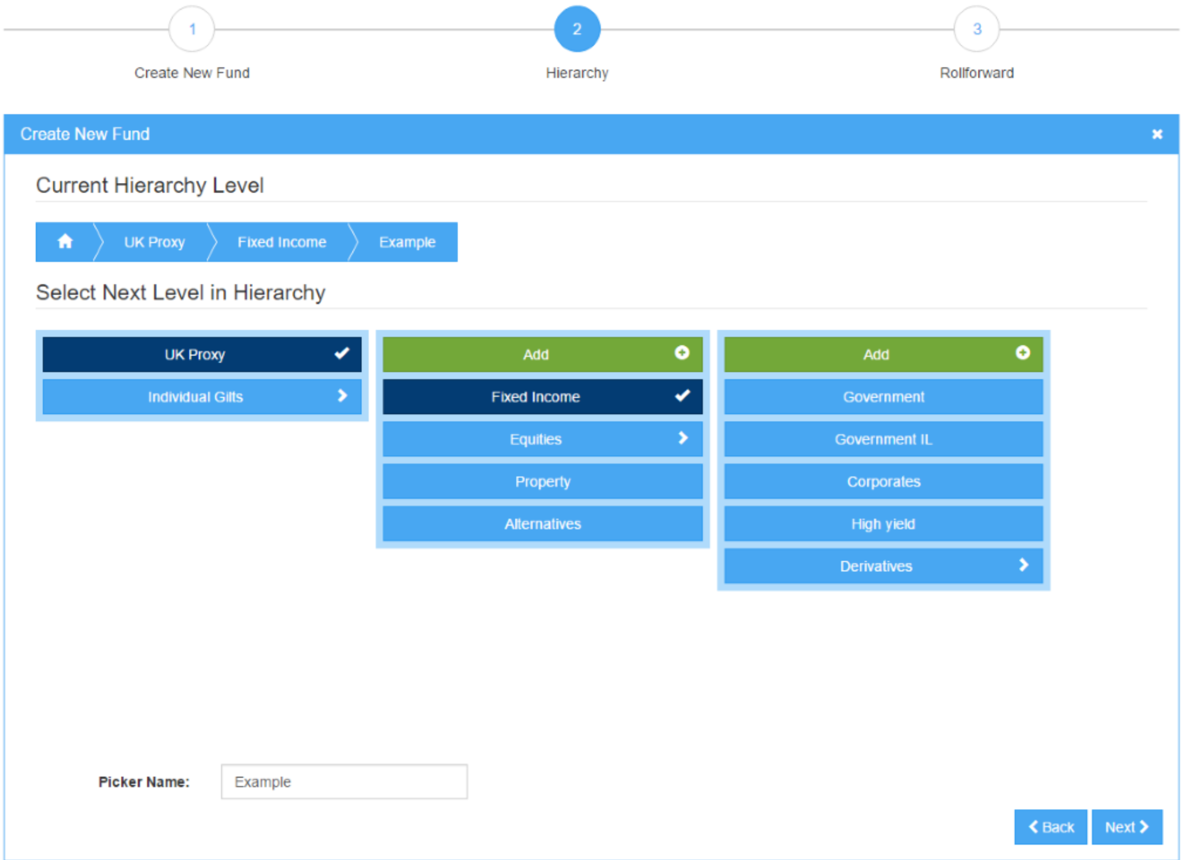
Step 2: Hierarchy

Hierarchy determines where the fund will appear in the fund pickers.

To add a new level to the hierarchy, click **Add** and enter the name.

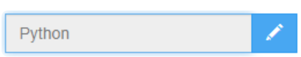
Picker Name will appear in fund pickers across PFaroe. This may differ from the fund name.

For example, the Benchmark Funds *UK Corp 0-5* and *UK Govt 0-5* both have a **Picker Name** of *0-5*, but they appear in different areas under the hierarchy.



Step 3: Roll forward

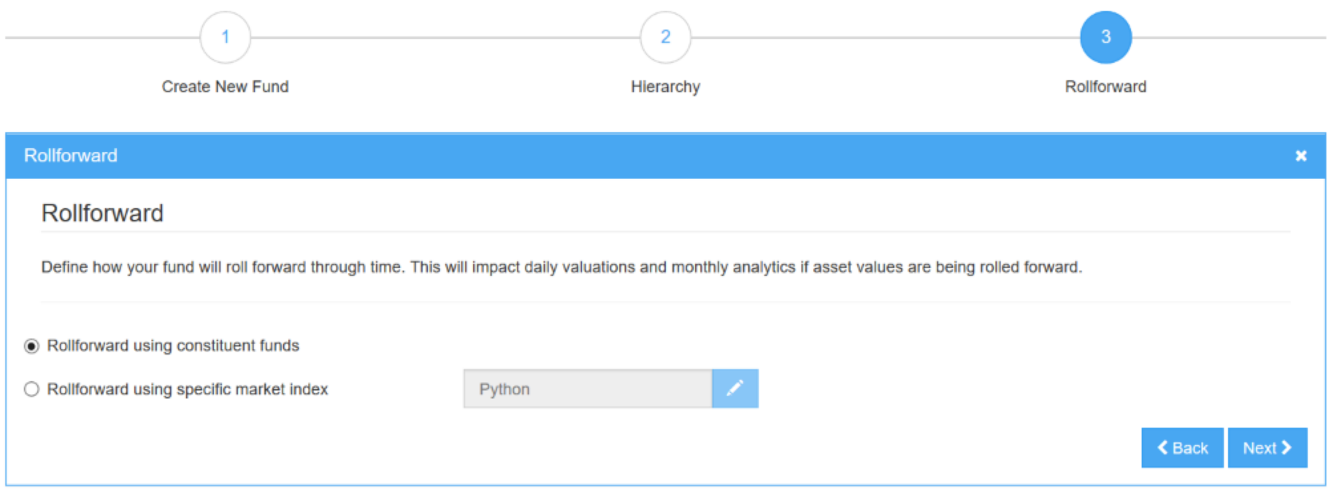
To specify a market index for calculating the fund's daily values:

- Select **Rollforward using specific market index**
- Click the **Edit** button 

- Enter a market index expression. This can be entered directly, or using various helpful options:
    - Click an expression from the **Example Expressions** section to use it as a starting point
    - Click on an index in the **Available Market Indices** section to insert it into your expression. You can search by name and code.
    - Enter a date and click **Evaluate** in the **Evaluate Expression** section to review the calculated output
- Click **Confirm** to validate and store the expression

To use a fixed value enter an expression of 1. This is generally appropriate for a derivative fund, or a fund where rollforwards are not required.

To base the calculation on the underlying funds in a **Fund of Funds**, select **Rollforward using constituent funds**.



Step 4: Security context

You will only see this section if you have the ability to create funds under multiple client or user groups.

To choose a group, select it from the dropdown.

Editing a Fund

Once created, Funds are effectively locked.

Click **Edit** to change:

- The **Picker Name** (but not the fund name)
- The **Open Date**
- The **Close Date** including whether or not a fund is **Ongoing**

Click **Copy** to add a new fund using the settings from an existing Fund. This will not add any **Fund Updates**.

Deleting a Fund

You cannot delete funds that have a released **Fund Update**.

To delete a fund:

- Unrelease all Fund Updates
- Click **Delete**

Warning! Take care when unreleasing and deleting funds. If an allocation refers to a fund which is subsequently deleted, the asset analytics will no longer be available.

Fund Groupings

The Grouping of a fund determines how it will be aggregated into an asset class category.

These categories are used in various reports, charts, displays, and other elements across PFaroe.

Grouping	Asset Class		Grouping	Asset Class
Absolute Return	Fixed Income		High Yield	Fixed Income
Alternatives	Alternatives		High Yield Long	Fixed Income
Asian Equity	Equity		High Yield Medium	Fixed Income
Bond Future	Fixed Income		High Yield Short	Fixed Income
Cash	Cash		High Yield Ultra Long	Fixed Income
CDS	Fixed Income		Inflation LDI	Fixed Income
Commodities	Alternatives		Inflation Swap	Fixed Income
Corporate	Fixed Income		Infrastructure	Alternatives
Corporate A	Fixed Income		Interest Rate Swap	Fixed Income
Corporate AA	Fixed Income		Loan funds	Fixed Income
Corporate AAA	Fixed Income		Multi-Asset Credit	Fixed Income
Corporate BBB	Fixed Income		Multi-Asset Fund	Alternatives
Corporate Long	Fixed Income		Nominal LDI	Fixed Income
Corporate Medium	Fixed Income		North American Equity	Equity
Corporate Short	Fixed Income		Other	Other
Corporate Ultra Long	Fixed Income		Private Equity	Alternatives
DGF	Alternatives		Property	Property
EAFE Equity	Equity		Real Estate	Real Estate
Emerging market debt	Alternatives		Real LDI	Fixed Income
Emerging Market Equity	Equity		REIT	Property
Equity	Equity		STRIPS	Fixed Income
Equity Index Future	Equity		STRIPS Long	Fixed Income
Equity Index Option	Equity		STRIPS Medium	Fixed Income

Grouping	Asset Class		Grouping	Asset Class
Equity-Linked Bonds	Fixed Income		STRIPS Short	Fixed Income
Equity-Linked LDI	Fixed Income		STRIPS Ultra Long	Fixed Income
European Equity	Equity		Swaption	Fixed Income
Fixed Income	Fixed Income		TIPS	Fixed Income
FX Forward	Fixed Income		TIPS Long	Fixed Income
Global Equity	Equity		TIPS Medium	Fixed Income
Government	Fixed Income		TIPS Short	Fixed Income
Government IL	Fixed Income		TIPS Ultra Long	Fixed Income
Government IL Long	Fixed Income		Total Return Swap	Fixed Income
Government IL Medium	Fixed Income		Treasuries	Fixed Income
Government IL Short	Fixed Income		Treasuries Long	Fixed Income
Government IL Ultra Long	Fixed Income		Treasuries Medium	Fixed Income
Government Long	Fixed Income		Treasuries Short	Fixed Income
Government Medium	Fixed Income		Treasuries Ultra Long	Fixed Income
Government Short	Fixed Income		UK Equity	Equity
Government Ultra Long	Fixed Income		US Equity	Equity
Hedge Fund	Alternative		Unknown	Unknown

3.2.3 Fund Updates

A fund update holds information about the fund that is likely to be adjusted over time. An allocation, sensitivities, and expected returns are examples of the kind of data stored in an update.

Updates can be created as frequently as required, although we recommend a monthly or quarterly update cycle. The behaviour of the fund will more accurately reflect reality if the fund is updated regularly.

The Fund Updates screen allows you to

- Create a new fund update
- View, edit or delete existing updates
- Release updates

Creating a fund update

To create a fund update:

- Find the **Fund** in the Fund Management screen
- Click to view the Fund's updates
- Click **Create Update**

The process differs depending on the fund type.

In all cases, the update must be released before you can use it in an allocation in PFaroe.

Fund of Funds

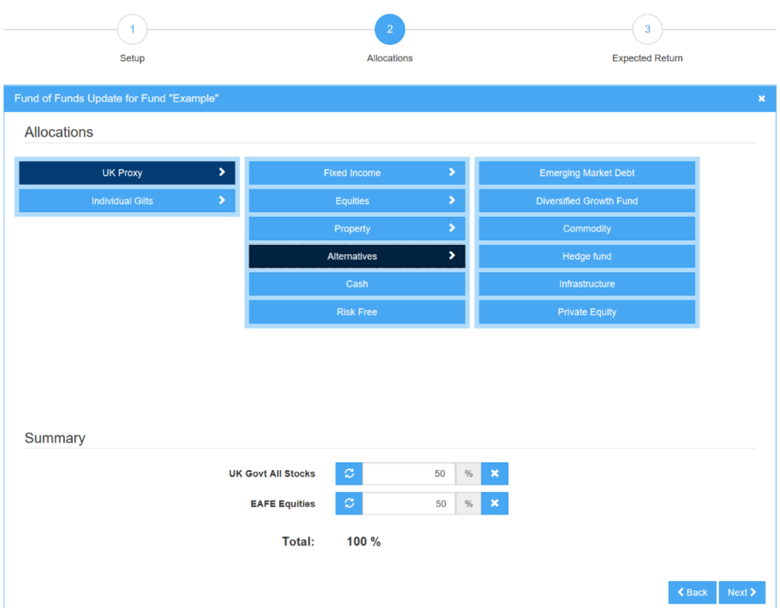
There are three steps:

1: Setup

- Select a **Start Date**
- Select an **End Date** or choose **Ongoing**
- A **Description** is useful to have, but not mandatory

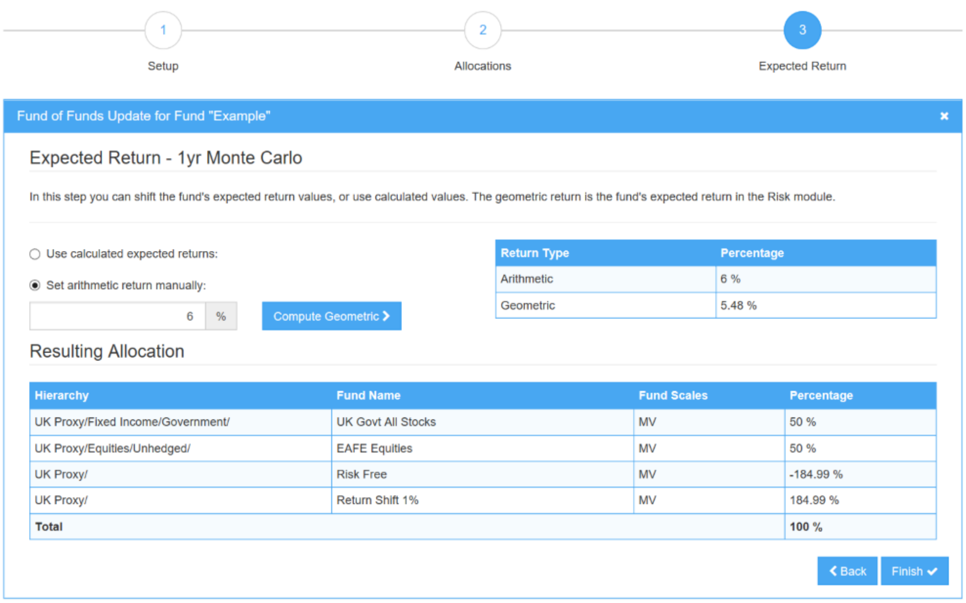
2: Allocation

- Select the constituent funds using the Fund Picker
- Enter the allocation percentage for each fund



3: Expected Return

- Choose **Use calculated expected returns** to derive expected returns from the stochastic scenario generator output
- Choose **Set arithmetic return manually** to override the calculated expected returns
    - **Note** This functionality is only available if (i) your Fund of Funds is set to Rebalance, and (ii) the update date is a month end
    - **Note** Using this option, two funds are added automatically. These add a flat return shift to the fund's return in both ALM and expected return calculations, and have no other effect on the fund's behavior.



Leveraged Fund

There are two steps:

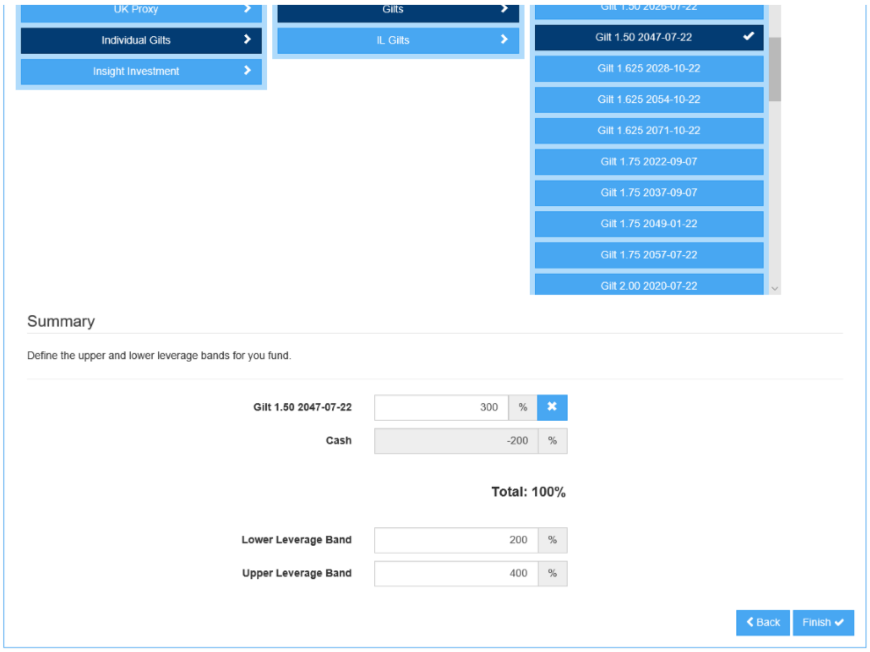
1: Setup

- Select a **Start Date**
- Select an **End Date** or choose **Ongoing**
- A **Description** is useful to have, but not mandatory

2: Allocation

- Select the underlying fund using the Fund Picker
- Enter an allocation
    - **Note** This must be between 101% and 1500%
- The Cash fund is used to leverage
- Enter **Lower Leverage Band** and **Upper Leverage Band.** These are used in ALM if the leverage ratio of your fund hits one of the bands.

- **Example** Consider a fund with a 250% leverage, a lower band of 200% and an upper band of 400%. If the leverage of that fund during an ALM projection exceeds 400% or falls below 200%, the leverage ratio would be restored to 250% by either adding or releasing cash.

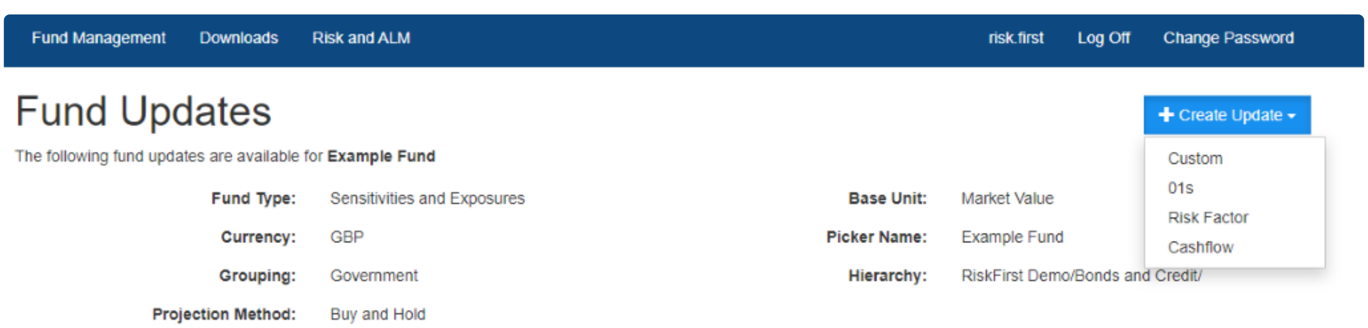


Sensitivities and Exposures Fund - Market Value

There are several different ways to add a **Fund Update** for a Sensitivities and Exposures fund with a base unit of Market Value. The best method depends on your intentions for modelling the fund and the data you have available. This is discussed in detail in the Fund Methodology section.

The options are:

- **01s:** allow you to build the framework to define the PV01s, CR01s and IE01s.
- **Risk Factor:** allows you to enter the fund's market value risk exposure
- **Cashflow:** allows you to use the cashflow profile of the fund



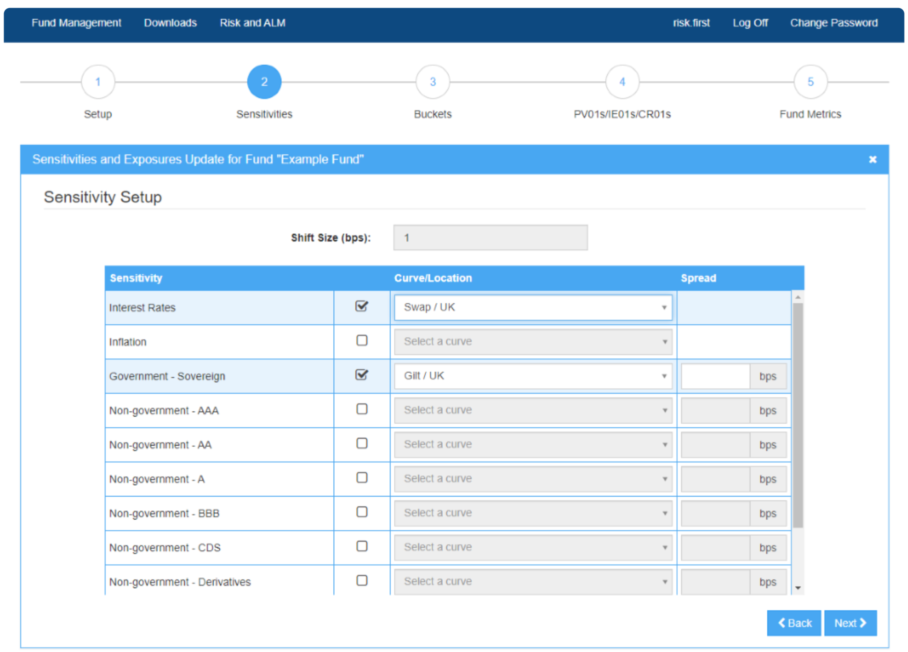
To update a Market Value Fund using 01s

1: Setup

- Select a **Start Date**
- Select an **End Date** or choose **Ongoing**
- A **Description** is useful to have, but not mandatory

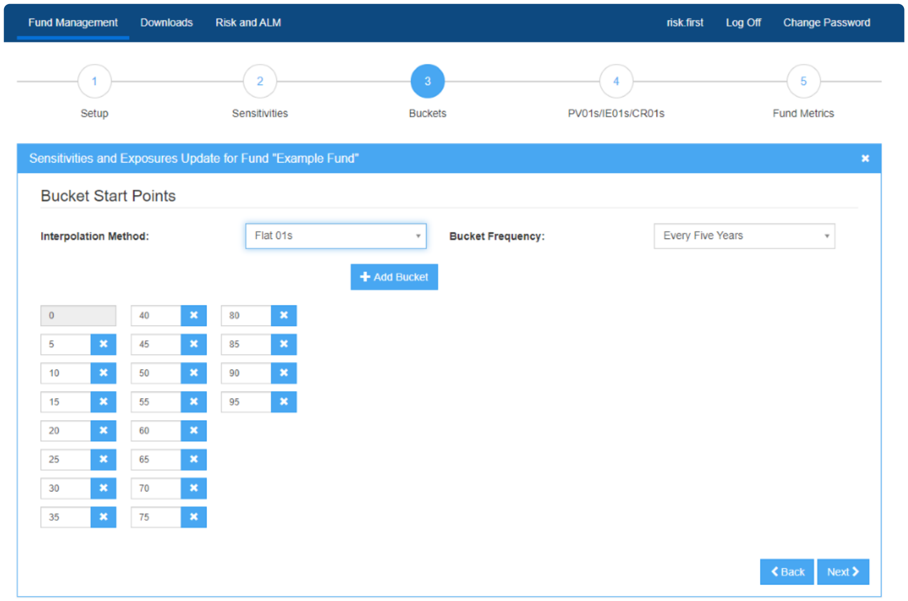
2: Sensitivities

- Check the box for each type of sensitivity
- Choose the risk free curve for each sensitivity
- Enter a **Spread** for each credit rating
    - **Tip** This is the market value weighted z-spread for that CR01 rating



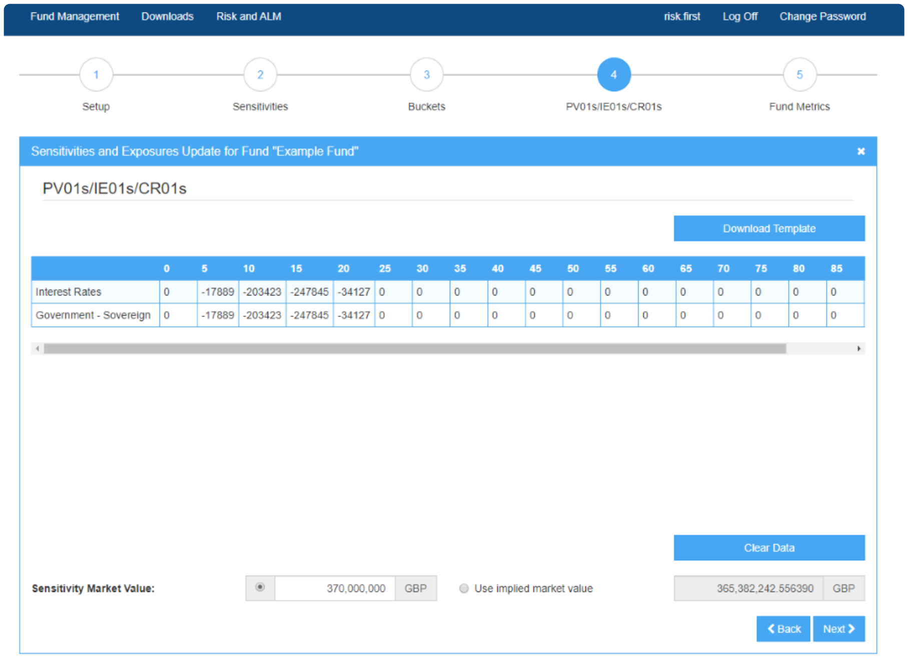
3: Buckets

- Choose a **Bucket Frequency**
    - Specify a **Custom** set of buckets by clicking Add Bucket and entering each start year
    - Click **Save Template** to make a custom set available in future
- Choose an **Interpolation Method**
    - This specifies how the sensitivities are converted into annual cash flows
    - For an **Annual** bucket frequency this will have no impact



4: PV01s/IE01s/CR01s

- Click **Download Template**
- Enter the sensitivities into the grey cells
- Copy the grey area (using standard Excel copy functionality)
- Paste into the designated area
- Fund Manager will calculate and display an implied market value
    - Click **Use implied market value** to use this value
    - Enter a **Sensitivity Market Value** to use as an override



5: Fund Metrics

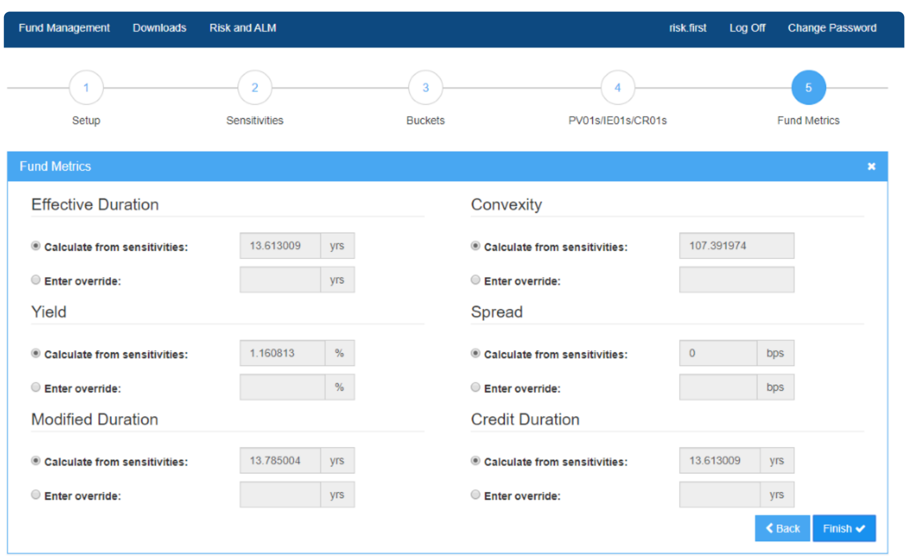
Fund Manager will calculate a range of metrics, based on the cashflows implied by the sensitivities.

The methodology is discussed in the Fund Methodology section.

To override any of these values:

- Click **Enter override**
- Enter the appropriate value

This does not change the underlying cashflows but changes the values displayed in the Assets module.



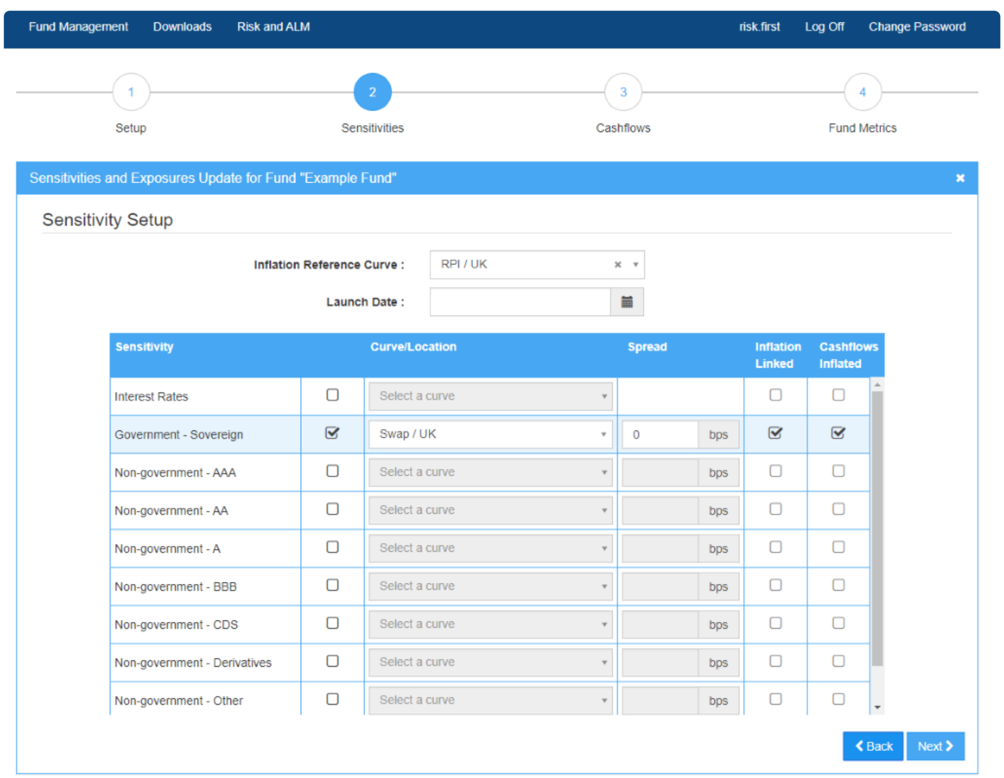
To update a Market Value Fund using Cashflows

1: Setup

- Select a **Start Date**
- Select an **End Date** or choose **Ongoing**
- Select cashflow timing as **Year End** or **Mid Year**
- A **Description** is useful to have, but not mandatory

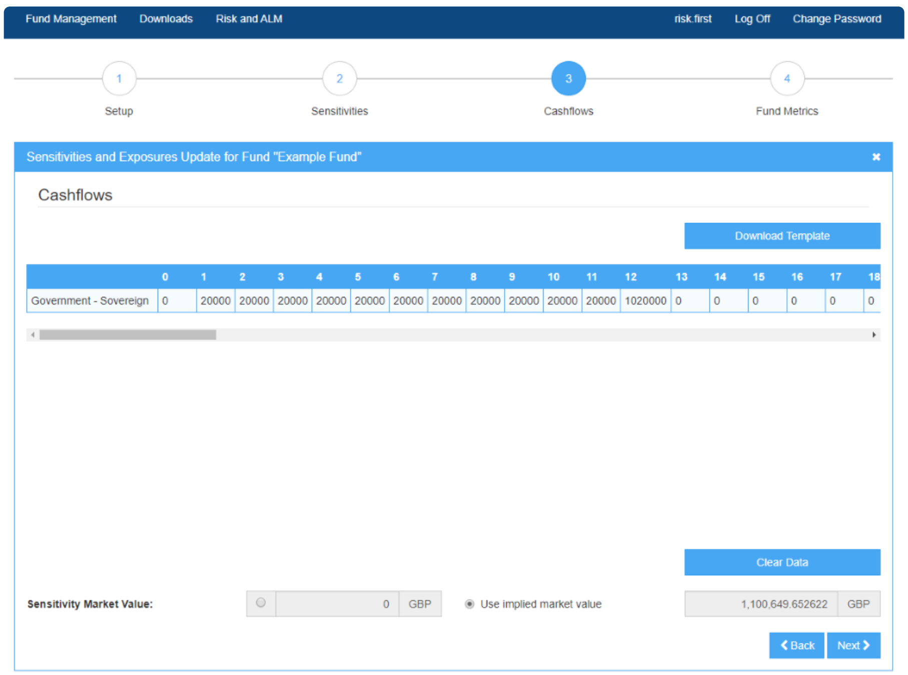
2: Sensitivities

- Check the box for each cashflow required
  - Check **Inflation Linked** if the cashflows have inflation sensitivity
  - Check **Cashflows Inflated** if the inflation linked cashflows already reflect assumed future inflation
- Choose the risk free curve for each cashflow
- Enter a **Spread** for each credit rating
  - **Tip** This is the market value weighted z-spread for that CR01 rating
- Choose an **Inflation Reference Curve** if the cashflows have inflation sensitivity
- Enter the **Launch Date.** This is used to inflate cashflows if required.



3: Cashflows

- Click **Download Template**
- Enter the annual cashflows into the grey cells
- Copy the grey area (using standard Excel copy functionality)
- Paste into the designated area
- Fund Manager will calculate and display an implied market value
  - Click **Use implied market value** to use this value
  - Enter a **Sensitivity Market Value** to use as an override



4: Fund Metrics

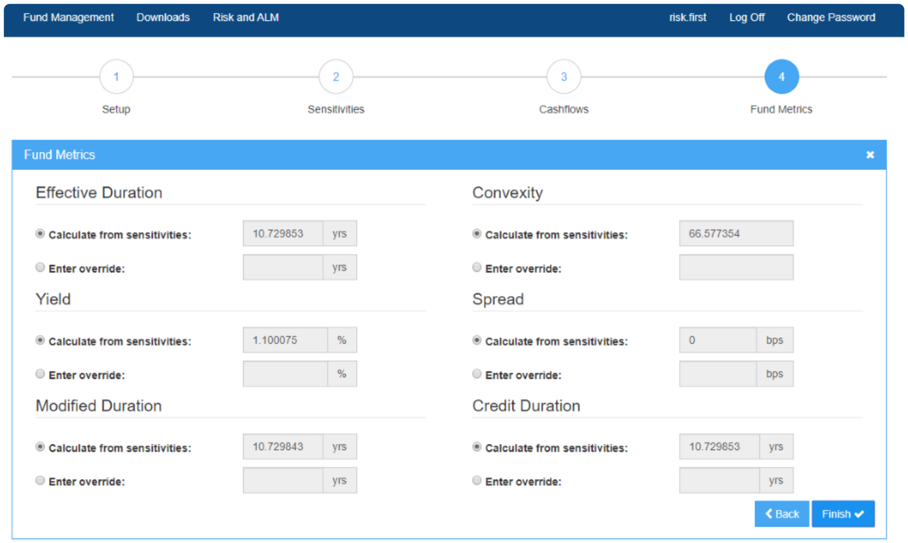
Fund Manager will calculate a range of metrics, based on the entered cashflows.

The methodology is discussed in the Fund Methodology section.

To override any of these values:

- Click **Enter override**
- Enter the appropriate value

This does not change the underlying cashflows but changes the values displayed in the Assets module.



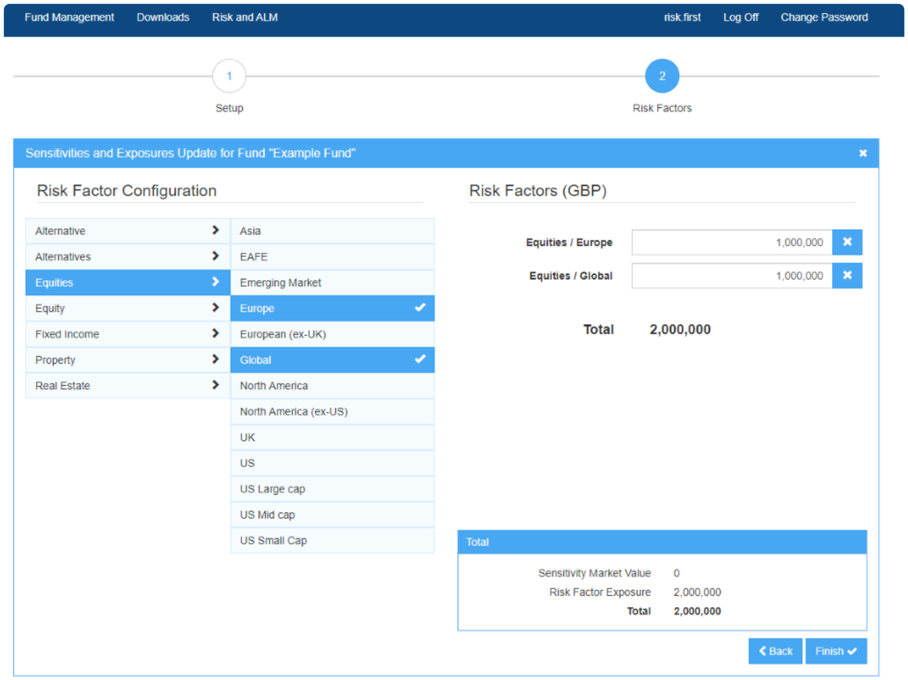
To update a Market Value Fund using Risk Factors

1: Setup

- Select a **Start Date**
- Select an **End Date** or choose **Ongoing**
- Select cashflow timing as **Year End** or **Mid Year**
- A **Description** is useful to have, but not mandatory

2: Risk Factors

- Select the required risk factors from the **Risk Factor Configuration** screen
- Enter the market value exposed to each risk factor



Sensitivities and Exposures fund - Notional

The steps are identical to a market value fund except for two differences in the PV01s/IE01s/CR01s step:

- The **Sensitivity Market Value** corresponds to the market value of the fund given the amount entered in the notional field below is allocated to the fund. For example, the sensitivity market value of a benchmark swap at initiation is 0.000001.
- Enter a value in the **Notional** field. This is value that the fund's PV01s/IE01s/CR01s are based on.

Risk Factors with Cashflows Fund

The steps are identical to a risk factor fund update, except for an additional Cashflow setup step.

- Click **Download Template**
- Enter the annual cashflows into the grey cells
- Copy the grey area (using standard Excel copy functionality)
- Paste into the designated area
- Fund Manager will calculate and display the Risk Factor Market Value, based on the sensitivities (and not the cashflows)
- Select the Cashflow type
    - **Constant** cashflows will not change through time
    - **Yield** type cashflows will grow with fund returns

Releasing Fund Updates

When you create an update, it has a Pending status.

To release a fund, click the **Release** icon to the right of the update.

Start Date	End Date	Description	Status	Created	User	
30/06/2017	Ongoing		Pending	23/08/2017		

Once a fund has been released it can be seen in the following modules immediately:

- Asset allocations
- Assets
- Combined
- All dashboard quadrants except the VaR quadrant
- Optimizer, excluding the 'Risk and Returns' tab
- Deterministic ALM

The fund will appear in Risk and Stochastic ALM after it has finished calculating. This typically takes up to 30 minutes but can vary.

Viewing and Editing Fund Updates

To view a fund update, click the **View Details** icon .

This displays the inputs and any calculated Fund Metrics.

To edit a Pending fund update, click the **Edit** icon .

To revert a Released fund update to Pending status, click the **Unrelease** icon . This will invalidate any allocations or valuations referencing this update.

To delete a fund update click the **Delete** icon .

Multi-Fund Updates

Multiple funds can be updated efficiently. Click **Multi-Fund Update** on the Fund Management screen.

The inputs are the same as described above, but entered using an Excel template.

1: Setup

- Select a **Start Date**
- Select an **End Date** or choose **Ongoing**
    - **Note** The Start and End dates will be the same for all funds being updated

- Select the funds to update using the fund picker
- Click **Download Template**

2: Template

- Fill in the grey fields in the Excel template
    - **Note** Different fund types with different inputs are shown on distinct worksheets
- Save the file
- Click **Upload** and select the file

3: Review

- The table sets out:
    - Validation feedback for each fund
    - Key details of each successful fund update. Click **Download** to get the details in an Excel spreadsheet
- To release one or more updates, select them and click **Release**
- To delete one or more updates, select them and click **Delete**

3.3 Fund Methodogy

Each distinct Fund type has a different approach and methodology which drives the fund behaviour, returns and so in within PFaroe DB.

3.3.1 Sensitivities and Exposures Funds

Sensitivities and Exposures funds can be used to model a wide range of assets, including equity and fixed income.

The inputs and point-in-time analytics are described below.

The future time analytics (used in stochastic VaR and ALM calculations) are described in the next section.

Inputs

Sensitivities and Exposures funds are defined using Fund Manager. Calculations at a given date will use the **Fund Update** applicable on that date.

The key inputs are:

- **Sensitivities** to interest rates, credit spreads and inflation, and expressed as:
    - 01s (PV01s, CR01s, IE01s) using annual or grouped "buckets"
    - Annual cashflows
- **Exposures** to a range of risk factors, expressed in currency terms

- Market Value

Scenarios

PFaroe can model each fund in a range of macroeconomic scenarios. These may be:

- the current market conditions, or "Base Scenario"
- alternate conditions specified through a What if?, for example:
    - adding a flat 1% shift to interest rates or inflation
    - decreasing equity prices by 20%
    - adding a relative shift to interest rates or inflation
    - increasing or decreasing credit spreads for specific ratings
    - using interest rate or inflation curves from a different date
- alternate conditions specified by other configuration, for example:
    - curve exposure calculations, where ranges of tenor points on each curve are shifted (whether in square shifts or overlapping "tents", in spot or forward space)
    - market events stresses, attempting to replicate historic shifts

Point-in-time analytics

In practice, a fund is generally used in an **Allocation** to specify an asset portfolio and its properties.

Various "point in time" outputs are available in this context, scaled and aggregated from each fund as appropriate:

- Cashflows
- What if? calculations
- Curve exposures
- Market events
- Yield, spread and duration metrics

Funds are also used in "future time" analytics, such as VaR, Deterministic ALM and Stochastic ALM.

Cashflows

In the base case the cashflows are derived as set out below.

In alternate scenarios, the cashflows are recalculated as required. For example, inflation linked cashflows will change if inflation is flexed.

Pricing

The market value of the fund is recalculated based on the cashflows and risk factors. In PFaroe these are typically viewed for an allocation, with scaling and aggregation as required. The key output could therefore be considered the percentage change in price, rather than the absolute price level.

- The cashflows are discounted using the respective discount rates to recover the hypothetical market value
    - Fixed and Real cashflows are discounted using the risk-free rate
    - Credit-risky cashflows are discounted using the risk-free rate plus spread
    - Floating cashflows are not discounted
- The market value is adjusted for exposures to any stressed risk factors

Additional metrics

Various other metrics are calculated for each fund, based on the inferred cashflows in each scenario. These include:

- Yield
- Spread
- Adjusted Credit Spread
- Modified Duration
- Effective Duration
- Credit Duration
- Duration Times Spread
- Convexity

Details of the calculations are set out below.

Modified Duration, Yield and Spread are not calculated for Notional funds.

The **Yield** is the single annually-compounded rate that discounts the visible cash flows to the implied market value (***IMV***).

The yield ***y*** solves the equation $IMV = \sum_t \frac{CF_t}{(1+y)^t}$ for a set of cashflows $\mathbf{CF_t}$ each paid at time **t**.

Floating cashflows do not affect the yield calculation.

The **Spread** is the z-spread to the risk-free spot curve that discounts the visible cashflows to the implied market value (***IMV***).

The spread ***z*** solves the equation $IMV = \sum_t \frac{CF_t}{(1+r_t+z)^t}$ for a set of cashflows $\mathbf{CF_t}$ each paid at time **t**, with a risk free discount rate ***r***.

This means that:

- A risk-free cashflow will have a spread of zero
- A single rating credit bond will have a calculated spread that matches the input spread for the CR01s
- A fund with a mixture of credit rating sensitivities will have a spread which is a weighted average of the input spreads

Floating cashflows do not affect the spread calculation.

Adjusted Credit Spread

The adjusted credit spread z_{adj} solves the equation $IMV_{credit} = \sum_t \frac{CF'_t}{(1 + r_t + z_{adj})^t}$ for a set of credit-risky cashflows $\mathbf{CF'_t}$ each paid at time **t**, with a risk free discount rate r and an implied market value IMV_{credit}.

Where there are no risk-free cashflows, $z_{adj} = z$ (because $\mathbf{CF'_t} = \mathbf{CF_t}$ and $IMV_{credit} = IMV$)

i.e. the adjusted credit spread is identical to the spread.

Macaulay Duration is calculated as $D_{Macaulay} = (\sum_t \frac{tCF_t}{(1 + r_t + z)^t})\frac{1}{IMV}$ for a set of cashflows $\mathbf{CF_t}$ each paid at time **t**, with a risk free discount rate r and spread z.

Modified Duration is calculated as $D_{Modified} = \frac{D_{Macaulay}}{1 + y}$

Floating cashflows do not affect the Macaulay Duration or Modified Duration calculations.

Effective Duration is calculated as $D_{Effective} = \frac{MV_{-\delta} - MV_{+\delta}}{2MV\delta}$ where:

- ***MV*** is either the calculated Market Value of the fund, or the Notional. This depends on the Base Unit of the fund, decided in the initial fund setup.
- $MV_{+\delta}$ and $MV_{-\delta}$ are the implied market values when the risk free rate is increased and decreased (respectively) by δ

In this calculation δ is fixed at 0.01%.

Floating cashflows are reflected in the MV. This can lead to large differences between Modified Duration and Effective Duration, if the floating cashflows are material.

Credit Duration (or **Effective Credit Duration**) is calculated as $CD_{Effective} = \frac{MV_{-\delta} - MV_{+\delta}}{2MV\delta}$ where:

- ***MV*** is either the calculated Market Value of the fund, or the Notional. This depends on the Base Unit of the fund, decided in the initial fund setup.
- $MV_{+\delta}$ and $MV_{-\delta}$ are the implied market values when all credit spreads are increased and decreased (respectively) by δ

In this calculation δ is fixed at 0.01%.

Floating cashflows are reflected in the MV. It is broadly consistent with the Effective Duration.

Duration Times Spread (or **DTS**) is calculated as **Credit Duration** multiplied by **Adjusted Credit Spread**, both as described above.

The **Convexity** of a fund is calculated as $Convexity = \dfrac{MV_{-\delta} + MV_{+\delta} - IMV}{2MV\delta^2}$ where:

- ***MV*** is either the calculated Market Value of the fund, or the Notional. This depends on the Base Unit of the fund, decided in the initial fund setup.
- $MV_{+\delta}$ and $MV_{-\delta}$ are the implied market values when the risk free rate is increased and decreased (respectively) by δ
- ***IMV*** is the implied market value

In this calculation δ is fixed at 0.01%.

The convexity adjustment using this formula is $Convexity(\delta^2)$. Some definitions of Convexity may exclude the 2 in the denominator, and so include a factor of $\frac{1}{2}$ in the Convexity Adjustment formula.

Floating cashflows are reflected in the MV. It is broadly consistent with the Effective duration calculation approach.

> **Note** An alternate calculation for Modified Convexity would be $Convexity_{modified} = \dfrac{1}{IMV(1+y)^2} \sum_t \dfrac{CF_t(t^2+t)}{(1+r_t+z)^t}$. The convexity adjustment using this formula would be $\frac{1}{2}Convexity(\delta^2)$, so the convexity calculated would generally be double the value described above.
>
> Floating cashflows are not reflected in this calculation, so it may differ from Convexity calculated above where floating cashflows are material (in addition to the factor of 2 described above). It is consistent with the Modified duration calculation approach.
>
> This calculation is not implemented in PFaroe for Funds. However, it is the definition used for liability convexity calculations. This may lead to perceived inconsistencies.

Derivation of cashflows from sensitivities

Annual cashflows are inferred from the sensitivities specified at each tenor.

A set of credit risky, inflation-linked and risk-free cashflows are derived as set out below. These cashflows will replicate the input sensitivities.

A set of floating cashflows can also be generated. This is generally used either (a) to generate the floating leg of a swap or other derivative, or (b) to correct for small model differences. This is used (along with the cashflows) to replicate the input market value.

Note Credit risky, inflation-linked and risk-free cashflows can be entered directly. In this case, the floating cashflows are generated as described below.

Risk-free cashflows (simple case)

Where the only non-zero sensitivities input are PV01s, the derived nominal risk-free cashflow ***N*** implied by an input PV01, risk free rate ***r*** and shift δ is calculated as:

$$N = PV01 \frac{1}{(1+r+\delta)^{-W} - (1+r)^{-W}}$$

This is obtained by rearranging the equation for PV01 derived as follows:

- The present value of a nominal cashflow ***N*** at duration ***W*** discounted using risk free rates ***r*** is $PV = N(1+r)^{-W}$
- The present value when the risk-free rate ***r*** is increased by δ is $PV^{+\delta} = N(1+r+\delta)^{-W}$
- The PV01 is then calculated as $PV01 = PV^{+\delta} - PV = N[(1+r+\delta)^{-W} - (1+r)^{-W}]$

Note this definition of PV01. Alternate definitions could include $PV - PV^{-\delta}$ or $\frac{PV^{+\delta} - PV^{-\delta}}{2}$.

Credit risky cashflows

A credit risky cashflow N_{credit} implied by the CR01, risk free rate ***r***, initial credit spread ***z*** and shift δ can be calculated as:

$$N_{credit} = CR01 \frac{1}{(1+r+z+\delta)^{-W} - (1+r+z)^{-W}}$$

This is derived in a similar way to the risk-free cashflow described above.

This example illustrates a single CR01, with a single spread. This is extended to multiple credit ratings by specifying multiple $\mathbf{CR01_{rating}}$ sensitivity inputs, with multiple z_{rating} spreads; these are each treated independently to produce multiple N_{rating} cashflows.

The choice of ***z*** will have a small impact on the cashflow calculations, and should be considered carefully.

Using our definitions:

- the PV01 of such a cashflow would be calculated as $PV01 = N[(1+(r+\delta)+z)^{-W} - (1+r+z)^{-W}]$
- the CR01 is calculated as $CR01 = N[(1+r+(z+\delta))^{-W} - (1+r+z)^{-W}]$

It can be seen here that CR01=PV01, i.e. the formula is identical whether the delta is applied to ***r*** or ***z***.

Inflation-linked cashflows

An inflation linked cashflow N_{real} implied by the input IE01, risk free rate ***r***, inflation ***i*** and shift δ can be calculated as:

$$N_{real} = IE01 \frac{(1+r)^{W}}{(1+i+\delta)^{W} - (1+i)^{W}}$$

This is derived in a similar way to the risk-free cashflow, but noting that a real cashflow N_{real} at the valuation date would result in a nominal cashflow **C** at duration **W** with inflation ***i*** of $C = N_{real}(1+i)^W$.

This cashflow is assumed to be discount rate sensitive but not credit risky. Its PV01 is therefore calculated as $PV01_{real} = N_{real}(1+i)^W[(1+(r+\delta)+z)^{-W} - (1+r+z)^{-W}]$.

Risk-free cashflows

We first generate inflation-linked and credit risky cashflows as described above. These both contribute to the overall input PV01.

The remaining PV01 is calculated simply as $PV01_{fixed} = PV01 - PV01_{real} - PV01_{credit} = PV01 - PV01_{real} - CR01$

This is used to infer a purely risk-free, fixed cashflow calculated (using the formula above) as $N_{fixed} = PV01_{fixed}\frac{1}{(1+r+\delta)^{-W} - (1+r)^{-W}}$

Inference methods for non-annual sensitivities

Where sensitivities are 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.

- Flat 01s: The sensitivity is divided evenly across each tenor of the bucket
  - **Note** The cashflows will show a downward sloping profile because the duration increases with each tenor
- Bullet: The sensitivity is attributed to the left-hand edge of the bucket
  - **Note** This is effectively a shorthand for entering zero at non-specified tenors
- Midpoint:

Floating cashflows

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.

There are two key options available to users:

- **Cash on Account**. This is a single cash amount added to the IMV to produce the input market value.
  - In point-in-time calculations, it contributes to the total value but not any sensitivities, and so can affect some of the metrics
  - In future time calculations, it accrues interest at the risk-free rate, and is never realized as a cashflow
- **Floating legs**. This is a set of floating cashflows which is the same shape as the aggregate cashflows, scaled to give the input market value when added to the IMV.
  - In point-in-time calculations, this...

- In future time calculations, they are treated in the same way as other cashflows. They will be realized as a cashflow when the fund is set to "buy and hold".

The **Cash on Account** option is typically used to correct for small modelling differences.

The **Floating legs** option is typically used for derivatives.

For example, an interest rate swap and a bond may have the same sensitivity profile, and will therefore infer the same cashflows. However, the market value of the swap may be zero (or close to it), while the bond will not. The sensitivities do not resolve the existence of the corresponding floating leg of the swap, so the **Floating legs** method is used to generate this.

Future time projections

This section describes the behavior of Sensitivities and Exposures funds within PFaroe's two forecasting modules:

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

Inputs

Sensitivities and Exposures funds are defined using Fund Manager. Calculations at a given date will use the **Fund Update** applicable on that date.

The key inputs are:

- **Sensitivities** to interest rates, credit spreads and inflation, and expressed as:
  - 01s (PV01s, CR01s, IE01s) using annual or grouped "buckets"
  - Annual cashflows
- **Exposures** to a range of risk factors, expressed in currency terms
- Market Value
- **Projection Method**

The first three of these are used in the point-in-time analytics. The final item relates to how cashflows at future time steps are derived from the inputs, and is specific to future time projections.

Scenarios

PFaroe can model each fund in a range of macroeconomic scenarios. These may be:

- Deterministic scenarios:
  - derived from current conditions using a "Follow Forwards" approach
  - derived from current conditions, with user-defined stresses applied to yields, spreads, inflation, risk factors and realised conditions
  - specified by the user

- Stochastic scenarios:
  - using output from Moody's Scenario Generator
  - using date from alternative scenario generators

In each case the scenarios include:

- curves used to value fixed income assets and liabilities
- returns on a range of asset classes
- realized inflation indices

Future time analytics

In an ALM context, funds may generally be bought and sold at each timestep, and may generate cashflows (for example in the form of coupons or maturities).

The key outputs for a fund are therefore:

- Cashflows
- Pricing

These are used to calculate fund returns and generated cashflows over each projection timestep.

Cashflows

Cashflows at T_0 are discussed in the Point-in-time analytics section.

Cashflows at future timesteps are projected in different ways, depending on the **Projection Method**:

Using the **Buy and Hold** method:

- Expected cashflows are paid each year as they come due. Such generated cashflows are held as cash on account and accrue interest at the risk free rate.
- Future cashflows effectively move one year closer each year

This method is typically used for funds representing directly held assets, for example those intended to hedge liabilities. It may also be used for funds with fixed maturities, or individual bond holdings.

Using the **Constant Reinvestment** method:

- The fund is held for one timestep, and its price and cashflow are calculated
- It is then effectively reinvested into an identical asset for the next timestep

This method is typically used for managed funds with a broadly constant duration.

In both cases, real cashflows are increased with realized inflation.

Under a Buy and Hold approach, (effective) duration would typically decrease, reaching zero when all cashflows have been paid; under the Constant Reinvestment approach the duration would remain broadly constant (ignoring changes due to market conditions).

Pricing

Prices are calculated based on the projected cashflows described above, projected using the inflation curves from the current (stochastic or deterministic) scenario, and discounted using the relevant discount curves.

A calibration step is required to ensure consistency between the stochastic curves and the market curves used in setting up the fund.

Calibration of stochastic curves

Differences between the market curves at the valuation date and the equivalent initial T_0 curves provided by an Economic Scenario Generator (SG), may arise for various reasons including:

- The curves are calibrated at different dates - for example, where monthly asset projections are calculated but SG calibrations are only provided quarterly
- The calibration of the initial conditions in the SG has not perfectly replicated market curves, or used a different source curve
- No equivalent curve is available (for example, credit curves may not be available for all ratings)

The calibration approach taken ensures that the dynamics of the fund is consistent with the dynamics of the SG data. However, where the calibration is material this may lead to questionable results.

For risk free curves, inflation and sovereign curves, PFaroe will:

- Calculate a tenor-by-tenor shift from the differences in annual forward rates underlying the market curve and T_0 curve from the SG
- Add these forward shifts to SG forward curves at subsequent timesteps, indexed by time from the valuation date
  - i.e. At timestep 3, the first annual forward will be increased by the fourth forward shift, the second annual forward will be increased by the fifth forward shift, and so on

For credit curves, PFaroe will:

- At T_0: Use the risk free curve, plus the risk free shift described above, plus the input spread
- At subsequent timesteps: Use SG credit curves, plus the risk free shift described above

Implications and limitations

This calibration approach is intended to ensure that the fund is consistent with the SG data. However, this may introduce issues, including:

- Where calibration shifts are material, results may not be as expected. This may be material when the market conditions have changed significantly between the SG calibration date and the fund valuation date.
- There is a discontinuity in credit curves between T_0 and T_1. This may be material if the input spreads are not consistent with the SG data.

Additional metrics

Effective Duration is calculated as $D_{Effective} = \frac{MV - MV_{+\delta}}{MV\delta}$ where:

- ***MV*** is either the calculated Market Value of the fund, or the Notional. This depends on the Base Unit of the fund, decided in the initial fund setup.
- $MV_{+\delta}$ is the implied market value when the risk free rate is increased by δ

In this calculation δ is fixed at 0.01%.

Floating cashflows are reflected in the MV.

Credit Duration (or **Effective Credit Duration**) is calculated as $CD_{Effective} = \frac{MV - MV_{+\delta}}{MV\delta}$ where:

- ***MV*** is either the calculated Market Value of the fund, or the Notional. This depends on the Base Unit of the fund, decided in the initial fund setup.
- $MV_{+\delta}$ is the implied market value when all credit spreads are increased by δ

In this calculation δ is fixed at 0.01%.

Floating cashflows are reflected in the MV. It is broadly consistent with the Effective Duration.

The **Convexity** of a fund is calculated as $Convexity = \frac{MV_{-\delta} + MV_{+\delta} - IMV}{2MV\delta^2}$ where:

- ***MV*** is either the calculated Market Value of the fund, or the Notional. This depends on the Base Unit of the fund, decided in the initial fund setup.
- $MV_{+\delta}$ and $MV_{-\delta}$ are the implied market values when the risk free rate is increased and decreased (respectively) by δ
- ***IMV*** is the implied market value

In this calculation δ is fixed at 0.01%.

The convexity adjustment using this formula is $Convexity(\delta^2)$. Some definitions of Convexity may exclude the 2 in the denominator, and so include a factor of $\frac{1}{2}$ in the Convexity Adjustment formula.

Timestep size

PFaroe uses annual timesteps for deterministic and stochastic projections.

Limitations of the fixed income fund methodology

Funds using sensitivities

Interpretation of the risk-free rate

In theory, we are free to pick any risk-free reference rate. The credit sensitivities and assumed spreads must be consistent with the reference rate.

At present, PFaroe only supports a single risk free rate for each location.

Compounding frequency

Sensitivities and Exposures funds in PFaroe work using annually compounded spot rates.

PFaroe market data is stored consistently, using annually compounded spot rates. Where curve data is entered as forward rates these are converted.

Economic Scenario data can be stored using annual or continuous compounding. In the latter case, it is converted to annual spot rates.

In general, unless otherwise specified, shifts are added arithmetically to spot rates.

Curve exposure flexes can be calculated using shifts to par rates. In this case, the spot curve is converted to a par curve, the shifts are applied, and the curve is converted back to a spot curve, before being fed into the annual calculations as standard.

Cashflow frequency and timing

Sensitivities and/or cashflows can be specified at annual tenors. More granular definitions are not supported.

The cashflows are assumed to be paid annually, either:

- At the end of each annual period with anniversaries on the valuation date, or
- At the mid-point of each annual period, using a simple "0.5 years" approach

For the purposes of mid-year cashflows, discount factors and inflation are calculated assuming flat annual forward rates, inferred from discount factors or accumulation factors based on annual spots.

For example, where the discount spot rate at period N is $\mathbf{r_N}$ and the spot rate at N+1 is $\mathbf{r_{N+1}}$, the mid-year discount factor $\mathbf{DF_{N+0.5}}$ can be calculated as $DF_{N+0.5} = \dfrac{DF_N}{(1+f_N)^{0.5}} = [(DF_N)(DF_{N+1})]^{0.5}$

In this calculation, $\mathbf{f_N}$ is the annual forward rate at timestep N and is calculated as $\dfrac{DF_N}{DF_{N+1}} - 1$.

Inflation lags

Inflation is modelled making no specific allowance for inflation lags. This effectively implies that inflation linked cashflows at time T are exposed to T years of future inflation, with no reflection of part-year historic inflation, or inflation lags in curves or cashflows.

For example, an index-linked cashflow in year 10 will have precisely 10 years of inflation exposure, typically with a 2-month lag (using PFaroe Gilt RPI curves after October 2023). An index-linked gilt maturing in 10 years would be exposed to a weighted average of the inflation index values two and three months before its redemption date.

Credit-risky inflation-linked instruments

Inflation-linked instruments are assumed risk free.

Credit risk can be captured by specifying CR01s; this will effectively model a risk-free inflation instrument with a shorted credit default swap overlay. This modelling will not fully reflect interactions between inflation and credit spreads.

Convexity

Convexity of sensitivity-based funds is reflected due to the cashflow modelling approach.

Non-linear payoffs

The methodology is designed for instruments with linear payoff functions (including conventional bonds). Convexity is naturally captured, as mentioned above.

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

These can be modelled using a different fund type described here.

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.

Floating rate notes

A floating rate note with one cashflow Q at time ***t*** has market value $\frac{Q(1+r)^t}{(1+r+z)^t}$ for risk-free rate ***r*** and credit spread ***z***.

This can be defined approximately using a Sensitivities and Exposures fund. This will infer 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).

However, changes to market conditions will not be reflected perfectly; the calculations are identical to a first-order expansion of the stress size, but include higher-order terms that become material for bigger shifts. For eaxample, 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%.

4 Holdings in PFaroe

4.1 Switching between plans

PFaroe Assets allows users to easily navigate between different financial plans. To switch plans, locate the dropdown arrow next to the plan name positioned in the top row of the interface. Selecting this arrow reveals a list of available plans for review and analysis.

4.2 Exposures

4.2.1 Assets by classification

This section provides a comprehensive view of your plan's assets at the selected valuation date. To navigate through different dates, utilize the date picker located in the top right corner of the page. For a tailored analysis, the 'configure groups' button enables selection of up to six classification levels to organize your plan's assets, classifications can be re-ordered using the grey oval shaped icons, which can be dragged. Users can expand or collapse rows within the assets grid to examine the assets under each classification. Sorting capabilities are available by clicking on column headers. Data export options to CSV or Excel formats are accessible via a right-click anywhere in the grid. The section can be resized, using the drag handle in the bottom left of the table.

Assets by classification

Moody's Rating > Industry Sector

Configure groups

Group	Name	Market Value (GBP)	Market Value %	Duration	Credit spread	Yield
Aaa (6)		1,264,536.43	1.58%	9.85 years	29 BPS	4.51%
Aa1 (3)		682,041.15	0.85%	6.79 years	33 BPS	4.63%
Aa2 (11)		2,468,499.44	3.09%	9.07 years	49 BPS	4.68%
Aa3 (10)		2,805,827.97	3.51%	2.91 years	44 BPS	4.88%
A1 (33)		8,752,042.26	10.95%	4.04 years	70 BPS	4.98%
A2 (14)		3,558,232.40	4.45%	5.31 years	60 BPS	4.95%
A3 (31)		8,244,416.67	10.31%	3.89 years	65 BPS	4.98%
Baa1 (83)		20,307,210.45	25.40%	6.41 years	120 BPS	5.47%
Baa2 (31)		7,519,951.01	9.40%	7.77 years	127 BPS	5.47%
Baa3 (6)		1,553,174.91	1.94%	2.99 years	98 BPS	5.21%
Ba1 (2)		483,187.72	0.60%	8.33 years	228 BPS	6.50%
Total		79,962,969.30	100.00%	4.30 years	69 BPS	3.87%

Figure 1 - Assets by classification broken down by rating and industry

4.2.2 Analysing cashflows

The Cashflows chart aggregates yearly expected cashflows of the plan. Users can refine the display by selecting a classification from the dropdown, adjusting how the bars are split, and choosing between undiscounted and discounted cashflow options. Clicking on a specific bar allows for a detailed breakdown of that year's cashflows at the security level. Additionally, a download link for the cashflows is provided.

Figure 2- Annual cashflow chart broken down by Moodys rating

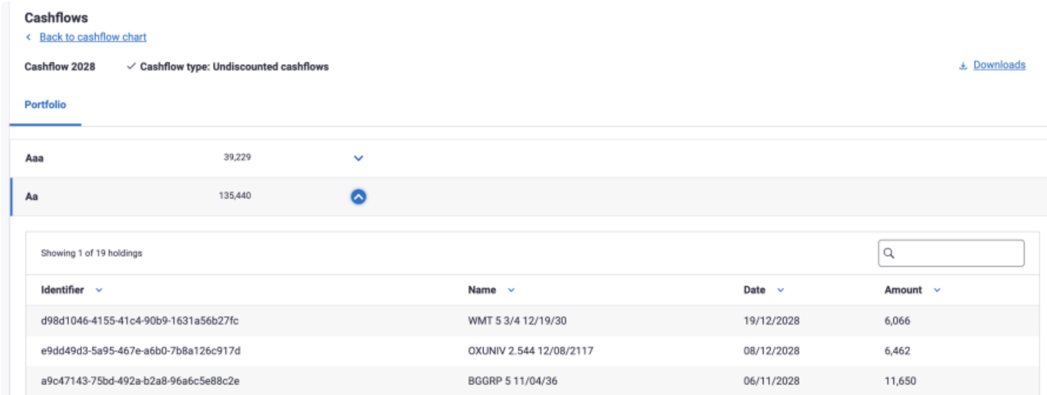


Figure 3 - Holding level cashflows for selected year

4.2.3 Sensitivity Analysis

PFaroe Assets presents a detailed sensitivity analysis table and chart, showcasing the plan's sensitivity to various curve tenors, including interest rates, inflation, and credit. Users can view results in terms of PV01 or key rate duration (KRD), facilitating a nuanced understanding of the plan's market risks.

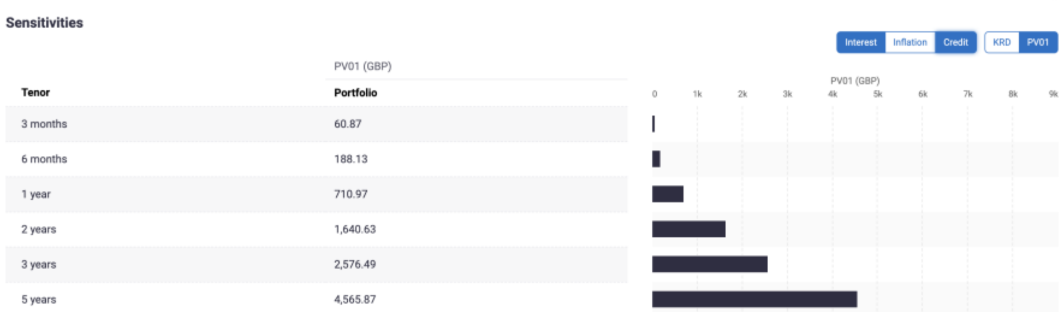


Figure 4 – Sensitivities by curve tenor

4.3 Holdings

The Holdings page lists every asset within the plan, with options to expand rows for additional details on each asset. This feature offers an in-depth view of the plan's investment components.

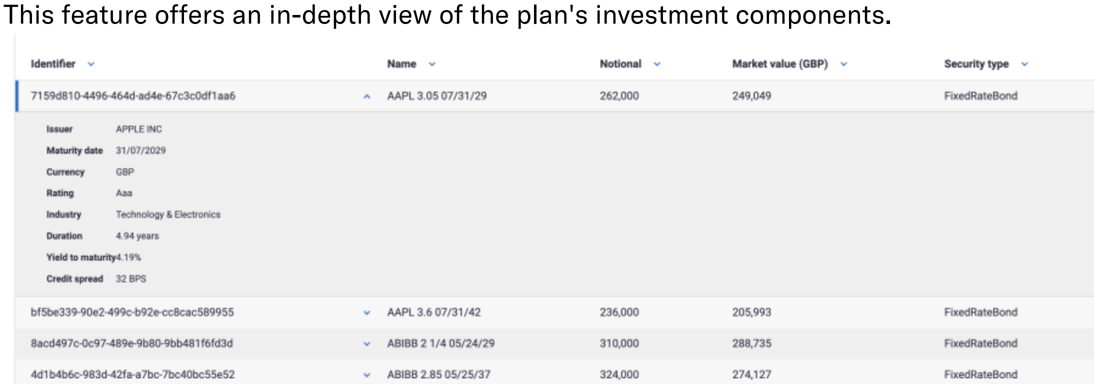


Figure 5 - Holdings with expanded view on a security.

4.4 What if

The What if module enables users to explore the implications of different asset allocation strategies or to model contributions and withdrawals. Adjustments to the total value above the table initiate a rebalancing process, which can be conducted at any classification or security level.
The interface provides a toggle between market value and percentage views, along with analytics to gauge the impact of amendments. Running a simulation generates a comprehensive set of analytics and cashflows.

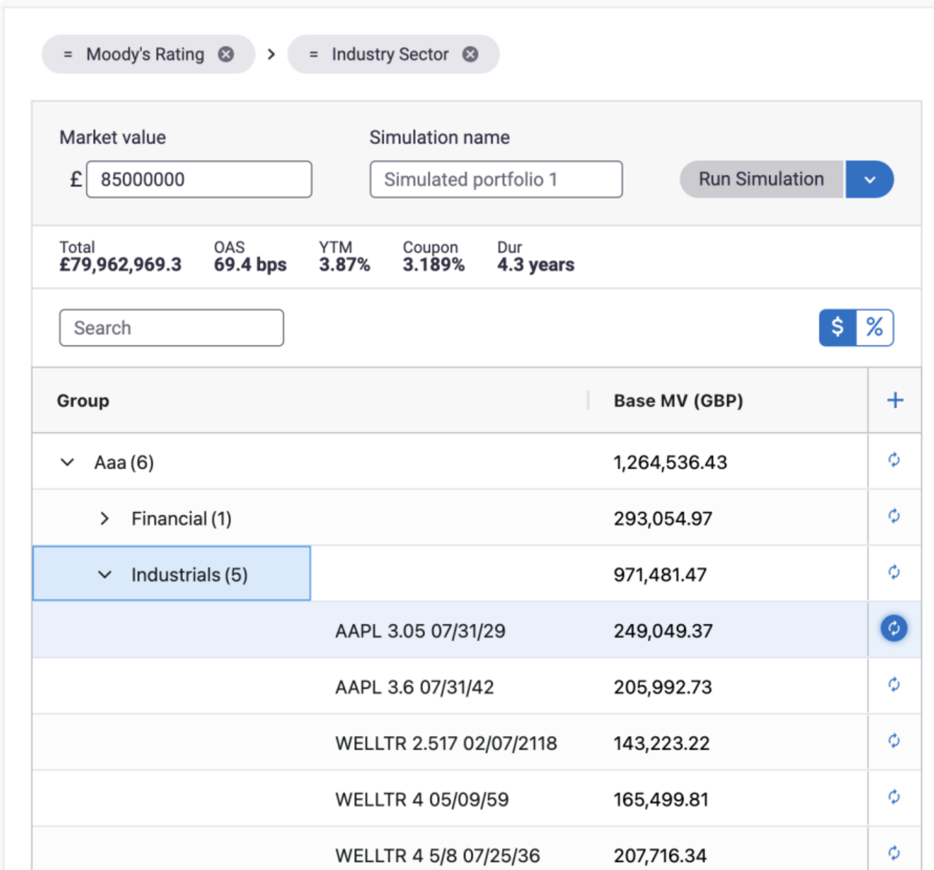


Figure 6 - What if in an unbalanced state, modelling a contribution. Click the blue button to allocate available cash to Apple bond
Simulated holdings runs can be saved for future usage by clicking on the '3-dots' menu on the right hand side of the simulations table

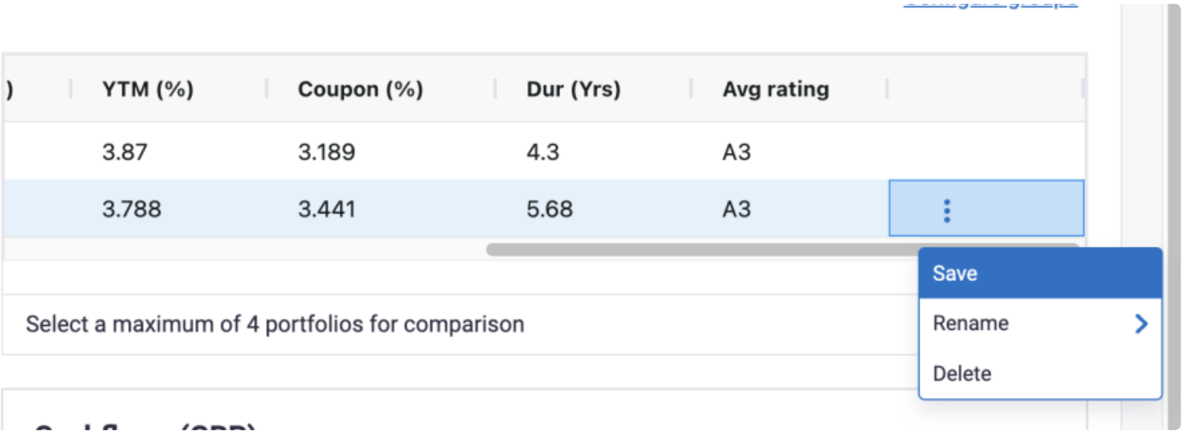


Figure 7 - Save or rename a simulation

4.4.1 Adding new assets to the plan

Users can augment their plan's asset portfolio by clicking the '+' button above the grid (see Figure 6), accessing a database of available assets. The search functionality supports ISINs, CUSIPs, SEDOLs, asset names for precise asset identification. Selected assets can be added and allocated just like any existing asset in the plan.

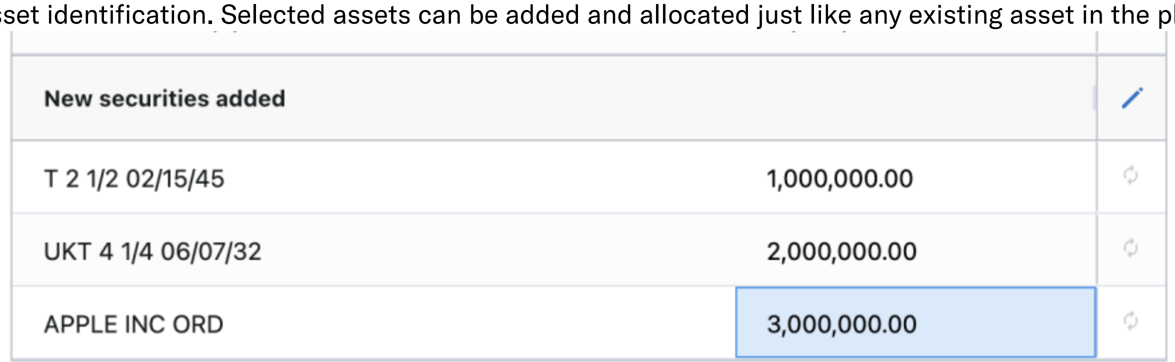


Figure 8 - Example of adding assets to a plan in What if

4.5 Stress testing

The Stress Testing module offers advanced capabilities for re-evaluating the plan under altered market conditions. Users can specify detailed stress scenarios across multiple factors, including interest rates, inflation, credit spreads, equity, and FX (the factors available are determined by the sensitivity of the plan). The module supports both global shifts and fine-grained adjustments based on asset classifications. Results, accessible post-calculation, can be broken down to the security level, providing a granular analysis of stress impacts.

Stress tests persist across sessions and their values will be recalculated each time a new valuation date is made available. The stress test scenarios created are available in the what-if module by selecting the dropdown arrow next to 'Run simulations.

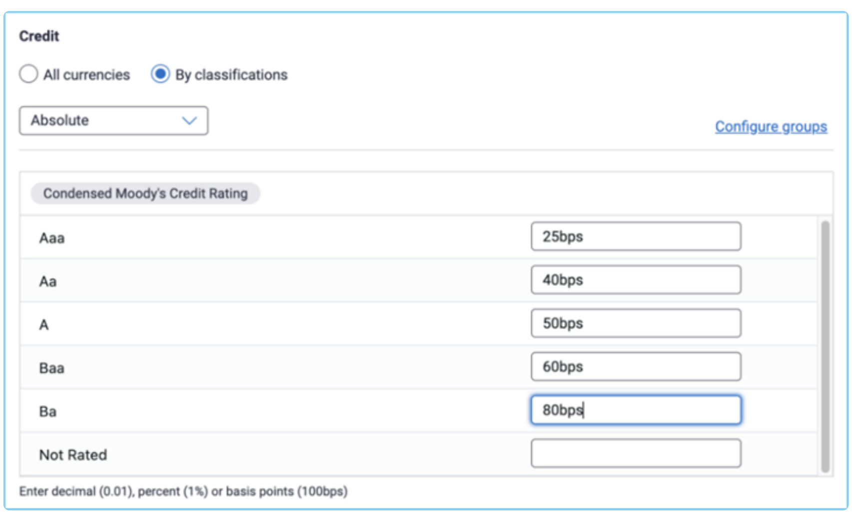
a. Stress types available per factor

Factor	Absolute	Absolute non-parallel	Relative
Interest rate	✓	✓	✓
Inflation	✓	✓	✓
Credit	✓		✓
Equity			✓
FX			✓

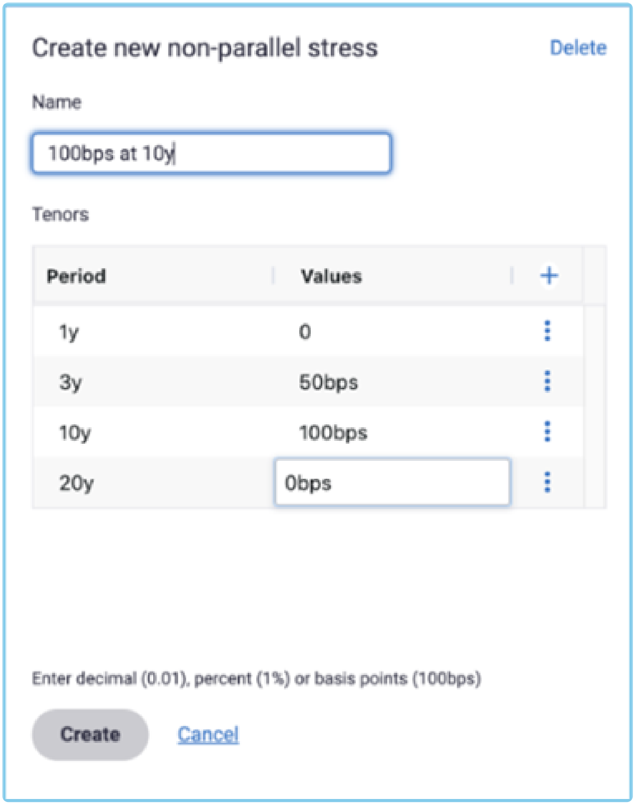
b. Results of different stress criteria

Factor	Shift type	Underlying market data	Shift amount	Output market data
Interest rate	Relative	3%	10%	3.3%
Interest rate	Absolute	4%	100bps	5%
Inflation	Absolute	5%	0.01	6%
Inflation	Absolute	6.4%	-1%	5.4%
FX	Relative	1.25	10%	1.375
Equity	Relative	362.66	2.5%	371.7265

c. Figure 9 - credit spread shifts being defined by Moody's rating.



d. Figure 10 - Non-parallel shifts can be applied to curves



e. How stresses are applied prior to repricing an instrument for the stressed MV

Interest rate

- Parallel shifts - all interest rates in the curve are changed by the same amount
- Non-parallel shifts - interest rates at the indicated tenor are shifted by the amounts indicated. The result is a triangular shift such that the peak is at the indicated tenor.

Inflation

- Parallel shifts - all inflation rates in the curve are changed by the same amount
- Non-parallel shifts - inflation rates at the indicated tenor are shifted by the amounts indicated. The result is a triangular shift such that the peak is at the indicated tenor.

Credit

- The input/implied credit spread of the instrument is shifted by the amount indicated.

Equity

- The market value of the instrument is shifted by the amount indicated.

FX

- The market quote of the spot FX rate of the instrument is shifted if it contains the input currency. The shift is applied relative to the base currency of the portfolio. For instruments with multiple legs of different currencies, the leg with the corresponding quote is shifted.

4.6 Methodology

4.6.1 Equity

Instrument Description

The equity instrument is used to model the value of ownership interest.

Valuation Formula

$$DirtyValue = SpotPrice * NumberOfShares$$

$$CleanValue = SpotPrice * NumberOfShares$$

Trades for which only the market value is provided (line items) can also be modelled in this way.

4.6.2 Bond_Fixed Rate

Instrument Description

A fixed rate bond is a financial instrument that pays a fixed amount of interest at predetermined dates (coupon dates) until maturity. At maturity, the final redemption (redemption rate * nominal amount) is returned to the bond holder. The present value of the bond is the sum of all discounted (future) cashflows, including the redemption payment(s). The coupon cashflow depends on:

  - the fixed annual rate
  - the coupon frequency (how many coupons per year are paid)
  - the coupon basis (day count conventions)

The bond may have a redemption schedule which defines the dates at which redemption cashflows are paid and the amounts of these redemption cashflows. At each redemption date, the nominal amount is reduced by the redemption cashflow.

Valuation Formula

$V(t) = \sum_{i=1}^{n} DF(t, T_i) * (c * N(T_i) * \tau(T_{i-1}, T_i, basis) + R(T_i))$

$V(t)$ is the value of the fixed rate bond at time t
$DF(t, T_i)$ is the discount factor from t to the date T_i (*including spread*)
c is the fixed (annual) coupon rate
$N(T_i)$ is the nominal amount of the bond at date T_i (if a redemption schedule is provided, the nominal of the bond is reduced by redemption cashflows, otherwise, the nominal does not change on the coupon dates)
$R(T_i)$ is the redemption cashflow at date T_i
$\tau(T_{i-1}, T_i, basis)$ is the year fraction of the coupon period according to the day count convention specified by the coupon basis.

If the fixed rate bond is callable or putable (and a call schedule and/or a put schedule exists), a deterministic valuation under a yield curve is not possible. In this case a stochastic model must be used.

Stochastic Interest Rate Model

General Hull & White Model

Description

The General Hull & White model is a 1-factor interest rate model of the following form, where the short rate r's process is assumed to follow:

$dr = (\eta(t) - \gamma(t)r)dt + \sigma(t)dW\gamma(t) > 0$

$\eta(t)$ is the deterministic drift
$\gamma(t)$ is the mean reversion speed
$\sigma(t)$ is the volatility

In the pricing engine, these 3 parameters are assumed to be piecewise constant i.e., constant within the time interval dt. Therefore, the General Hull & White model may be regarded as a piecewise Vasicek model. For consistency with the market, these parameters are calibrated from market swap curves and swaption volatilities. dW is the increment of a Wiener process.

Fixed Rate Bond Valuation

The value of callable/putable bonds under a 1-factor interest rate model is calculated as follows:

1. A spot rate grid is constructed using the supplied number of grid points.

2. The dirty value of the instrument at the maturity date T is the sum of its maturity cashflows – call/put option exercise is assumed **not** to be allowed on maturity date.

$V(r(i), T) = R(T) + CF(T)$

$R(T)$ is the final redemption of the bond

$CF(T)$ is the coupon cashflow at the maturity date

$r(i)$ is the spot rate

3. Propagate back in time given the maximal length of a time step (i.e., building the grid in time direction) - we call it $maxdt$. Assuming we have the dirty callable / putable bond values at date t_2. The next considered date $t_1 (t_1 < t_2)$ is given by:

$max(date(maxdtdaysbeforet_2), coupondate(beforet_2), calldate(beforet_2), putdate(beforet_2), valuationdate, settlementdate, adateatwhichoneofthemodelparameterschanges)$

Therefore, it is possible to hit all key dates.

The life value $LBVr(i), t_1$ of the bond (i.e., the value of the bond under the assumption that it is not called at t_1 and between t_1 and t_2 is given as:

$LBVr(i), t1 = \int_{-\infty}^{\infty} DF(r(i), \xi, t_1, t_2) * P(\xi) V(r(i) + \xi, t_2) d\xi + CF(t_1)$

$DF(r(i), \xi, t_1, t_2)$ is the discount factor from t_2 to t_1, provided that the interest rate at t_1 is $r(i)$ and at t_2 is $r(i) + \xi$

$P(\xi)$ is the probability density that r_i at t_1 moves to $r(i) + \xi$ at t_2

$CF(t_1)$ is the coupon cashflow at t_1

The dirty value of the callable/putable bond is then given as:

$V(r(i), t_1) = min(Call + C_A ccrued, max(LBVr(i), t_1, Put + P_A ccrued))$ if the bond is callable and putable at t_1

$C_A ccrued$ is the call accrued interest at t_1

$P_A ccrued$ is the put accrued interest at t_1

$Vr(i), t_1 = max(LBVr(i), t_1, Put + P_A ccrued)$ if the bond is only putable at t_1

$Vr(i), t_1 = min(Call + C_A ccrued, LBVr(i), t_1)$ if the bond is only callable at t_1

$Vr(i), t_1 = LBVr(i), t_1$ if the bond is not callable/putable at t_1

4. Propagate backwards in time until the settlement date t_s is reached. Between settlement date and valuation date we proceed as above but without discounting in the integral.

The option value $OV(r, t)$ is given by:

$OV(r, t) = V(r, t) - BV(r, t)$

$BV(r, t)$ is the dirty price of the underlying bond

Note that, e.g., for a bond which is callable but not putable the option value is negative (as from the investor's point of view).

To apply additional spreads for callable/putable bonds, these can be added to the yield curve input during valuation.

4.6.3 Bond_Vanilla Floater (=Floating Rate Note)

Instrument Description

A vanilla floater is a financial instrument, where the coupon payments change with market conditions. A vanilla floater pays interest according to a floating reference rate paid at the end of each coupon period (coupon date) until maturity. At maturity the final redemption (redemption rate * nominal amount) is returned to the holder of the vanilla floater.
The present value of the bond is the sum of all discounted (future) cashflows, including the redemption payment(s). The coupon cashflow depends on:

- the floating reference rate;
- the coupon frequency (how many coupons per year are paid); and
- the coupon basis (day count conventions).

The bond may also have a redemption schedule which defines the dates at which redemption cashflows are paid and the amounts of these redemption cashflows. At each redemption date, the nominal amount is reduced by the redemption cashflow.

Valuation Formula

$V(t) = \sum_{i=1}^{n} DF(t, T_i) * cashflow(i) + DF(t, T_n) * R(T_n)$

$V(t)$ is the value of the vanilla floater at time t
$DF(t, T_i)$ is the discount factor from t to the date T_i (*including spread*)
$cashflow(i)$ is the cashflow at i-th coupon date (see vanilla floater cashflow formula below)
$R(T_n)$ is the redemption cashflow at maturity date of the vanilla floater
$\tau(T_{i-1}, T_i, basis)$ is the year fraction of the coupon period according to the day count convention specified by the coupon basis

Vanilla Floater Cashflow

The cashflow of a vanilla floater at coupon date i is defined as:

$$cashflow(i) = N(i) * \tau(T_{i-1}, T_i, basis) * min(Cap(i), max(Floor(i), Refrateweight(i) * L(T_{i-1}, T_i) + Margin(i)))$$

$N(i)$ is the notional amount of the vanilla floater at time i
$\tau(T_{i-1}, T_i, basis)$ is the year fraction of the coupon period according to the day count convention specified by the coupon basis
$L(T_{i-1}, T_i)$ is the floating reference rate of the vanilla floater at the fixing date for that time interval and tenor according to the coupon frequency (e.g., 12M for annual frequency, 6M for semi-annual coupon frequency, ...)
$Refrateweight(i)$ is a multiplicative factor for the floating reference rate in the i-th coupon period
$Margin(i)$ is an additive factor added to the (weighted) floating reference rate in the i-th coupon period

A vanilla floater can be valuated using a single yield curve (i.e., the reference rates and discount factors are calculated from the same curve) or a multi curve approach (reference rates are calculated from the forward yield curve and discount factors are calculated from the discount curve).

Reference rates may also be calculated from compounded risk-free rates. In contrast to LIBOR reference rates, which are fixed in advance for an interest rate period, the compounded in arrears methodology involves the aggregation of overnight reference rates over a period such that the final value is known at the end of the interest calculation period. The following features may be applied:

- A lookback or lag period which allows one to determine the compounded interest rate payment some days before the end of the interest calculation period
- A lockout period where the last overnight rate is repeated

4.6.4 Bond_Flipper

Instrument Description

A flipper is a financial instrument, which switches from one coupon type to another e.g., fixed-to-float which switches from being a fixed-coupon bond to a floating-coupon bond on a given date. In the fixed-coupon period the instrument behaves like a Bond_Fixed Rate and in the floating period the instrument behaves like a Bond_Vanilla Floater (=Floating Rate Note). The type of the flipper (fixed-to-float or float-to-fixed) defines the order of the switch.

Valuation Formula

The present value of a Flipper is the sum of all discounted (future) cashflows and the discounted redemption payment. Each coupon cashflow in the floating period is derived like that of the Bond_Vanilla Floater (=Floating Rate Note), while cashflows in the fixed period are derived like those of a Bond_Fixed Rate.

A Flipper can be valuated using a single yield curve (=single curve approach - the floating reference rates and discount factors are calculated from the same curve) or a multi curve approach (floating reference rates are calculated from the forward yield curve and discount factors are calculated from the discount curve).

4.6.5 Bond_Discount

Instrument Description

The discount bond instrument is used to model short-dated zero-coupon bonds and money market instruments such as treasury bills.

Valuation Formula

Currently valued using the Bond_Fixed Rate methodology:

- 100% redemption at maturity.
- Callability/putability is not considered.

4.6.6 Bond_Inflation Linked

Instrument Description

An inflation linked bond is a financial instrument whose cashflows change with inflation market conditions. A broad measure of prices such a domestic index like Retail Price Index (RPI) or Consumer Price Index (CPI) is used. Cashflows are adjusted according to the relative change in the inflation index at the end of each payment period. Relative changes of the inflation index can be measured on a yearly basis or according to the index value at fixed initial observation point. At maturity the redemption value (typically linked to the evolution of the inflation index) is returned to the holder of the inflation linked bond. Any lag (e.g., 3 months) to the observation date is included.

The value inherent in an inflation bond can be decomposed into two fundamental factors: a real rate of return, plus the compensation for the erosion of purchasing power arising from inflation.

Valuation Formula

The present value of an inflation bond is the sum of all discounted (future) coupon cashflows and the discounted redemption payment. Each coupon cashflow depends on the value of the inflation index, margin (if any), coupon factor, coupon frequency (which defines how many coupons per year are paid) and coupon basis (which defines according to which day count conventions year fractions of time differences are calculated).

$$V(t) = \sum_{i=1}^{n} DF(t,T_i) * cashflow(i) + DF(t,T_n) * R(T_n)$$

$V(t)$ = value of the inflation linked bond at time t.
$DF(t,T_i)$ = discount factor from t to the coupon date T_i (including credit spreads).
$R(T_n)$ = Redemption cashflow at maturity date of the inflation linked bond.
$cashflow(i)$ = coupon at i-th date (see inflation linked cashflow formula below).

Inflation Linked Cashflow

For year-on-year inflation indexation, the coupon cashflow of an inflation linked bond at coupon date i is defined as:

$$cashflow(i) = N * \tau(T_{i-1}, T_i, basis) * Min(CouponCap(i), Max(CouponFloor(i), Round(CouponFactor(i) * (\frac{I(sd_i)}{I(sd_i - 1y)} - 1) + Margin(i)))))$$

For indexation from an initial observation point, the coupon cashflow of an inflation linked bond at coupon date i is defined as:

$$cashflow(i) = N * \tau(T_{i-1}, T_i, basis) * Min(CouponCap(i), Max(CouponFloor(i), Round(CouponFactor(i) * (\frac{I(sd_i)}{I(t_0)} - 1) + Margin(i)))))$$

N = Notional amount of the inflation linked bond
$\tau(Ti - 1, T_i, basis)$ = year fraction of the coupon period according to the day count convention specified by the coupon basis.
$I(sd_i)$ = inflation index at the i-th coupon set date.
$I(t_0)$ = inflation index at the initial observation date.
$CouponFactor(i)$ = multiplicative factor on the inflation reference rate in the i-th coupon period.
$Margin(i)$ = factor added to the (weighted) reference rate.

Rounding is applied to the calculated coupon rate.

If the redemption cashflow is inflation linked, it is calculated as:

$$R(T_n) = N * Min(RedemptionCap(i), Maz(RedemptionFloor(i), RedemptionFactor(i) * \frac{I(T_n)}{I(t_0)} + RedemptionMargin(i)))$$

Otherwise, it is calculated as:

$$N * RedemptionRate$$

4.6.7 Bond_Asset Backed

Instrument Description

Asset backed securities are created from a portfolio/pool of income producing assets such as loans, leases, credit card receivables and bonds. The cashflows from these assets can be passed-through directly from the pool to the investor (minus costs for servicing this arrangement) or they can be structured in into tranches of similar credit quality (senior, mezzanine, equity) such that an investor participates in the tranche that matches their requirements best.

Valuation Formula

Asset-backed bonds are valued using the Bond_Fixed Rate, Bond_Vanilla Floater (=Floating Rate Note), and Bond_Inflation Linked methodologies.

Asset-backed Cashflows

Cashflows are adjusted for the following features:

1. Scheduled Amortization

2. Unscheduled Prepayments using a prepayment model selected from the following:

PSA

The Public Securities Association Standard Prepayment model is used for mortgage-backed securities (MBS) and collateralized mortgage obligations (CMO) where no factors are provided. For the baseline PSA100, the time zero annualized constant prepayment rate (CPR) is 0% which increases linearly each month by 0.2% such that the 30th month's prepayment rate is 6%. This is then held flat at 6% until the maturity of the security.

CPR

Where historical factors are provided and therefore a prepayment speed can be calculated, CPR or the monthly equivalent SMM (single monthly mortality) are used.

i. The outstanding periodic balance (e.g., monthly) is calculated to compare the expected vs actual pool factors, hence prepayment speed. Expected or scheduled balance is derived using the security's coupon rate:

$$ExpectedBalance_t = P / \frac{1 - (1 + C/m)^{-n}}{1 - (1 + C/m)^{-n+t}}$$

c = annual coupon %

t = 1, 2, ..., m

P = original principal i.e. expected balance at t = 0

m = number of payments per year e.g., 12 for monthly

n = term of the security in number of periods e.g., months

ii. Using the provided historical pool factors Actual Balance for each historical time t can be derived as

$$ActualBalance_t = P * PoolFactor_t$$

iii. CPR can then be calculated as

$$CPR_t = 1 - (ActualBalance_t / ExpectedBalance_t)^{12/t}$$

$$SMM_t = 1 - (1 - CPR_t)^{1/12}$$

iv. The most recent CPR is used to project future prepayment.

v. The principal will then be amortized by scheduled payments, unscheduled payments (prepayments) and interest payments.

$$FixedPayment = P/[\frac{1 - (1 + c/m)^{-n}}{c/m}]$$

$$InterestPayment_t = OutstandingPrincipal_t * c/m$$

$$ScheduledPrincPayment_t = FixedPayment - InterestPayment_t$$

$$UnscheduledPrincPayment_t = CPR_t * (OutstandingPrincipal_t - ScheduledPrincPayment_t)$$

$$Cashflow_t = InterestPayment_t + ScheduledPrincPayment_t + UnscheduledPrincPayment_t$$

Outstanding Principal on valuation date is calculated using the most recent pool factor.

vi. Adjustments for underpayments may be made to align cashflow paydown to recent history e.g., by adjusting the scheduled payments.

vii. Default CPR e.g., 6% can also be used where historical factors are not provided and a market or empirical estimate is available.

ABS

The Absolute Prepayment Speed model measures the monthly rate of prepayments as a function of the original principal. When measured from time zero, it can be simplified to:

$$ABS_t = (1/t) * (1 - ActualFactor_t / ExpectedFactor_t)$$

$$Factor_t = OutstandingPrincipal_t / OriginalPrincipal_t$$

For ease of reference this can be converted to SMM:

$$SMM_t = ABS_t/(1 - ABS_t * (t - 1))$$

This is converted to CPR and applied as in the CPR model.

Default ABS e.g., 0.5% can also be used where historical factors are not provided and a market or empirical estimate is available.

An inflation adjustment is applied for cashflows from inflation-linked ABS such as utilities backed pools.

The above models do not apply to securities where the expected principal paydown schedule is provided in full and to bonds that are only collateralized using a defined asset pool e.g., mortgage bonds.

4.6.8 Cash (Simple Loan/Deposit)

Instrument Description

The cash instrument is used to model simple loans and deposits and is a special (simplified) case of bond pricing.

Repurchase Agreements (Repos) can also be modelled using the cash instrument; collateral is not considered.

Valuation Formula

Valued using the Bond_Fixed Rate or Bond_Vanilla Floater (=Floating Rate Note) methodology depending on the coupon type:

- 100% redemption at maturity or amortizing schedule can be applied.
- Callability/putability is not considered.

4.6.9 Futures_Equity Index

Instrument Description

Equity index futures are derivative financial instruments. A futures contract is an agreement to buy or sell the underlying asset at a given future date for a given price. Futures contracts are normally exchange traded. Features of the contract (specifications) are standardized and available on the exchange website. Futures on equity indices are cash-settled.

Valuation Formula

The equity index futures price at valuation date is calculated as the future price of the underlying, allowing for risk-free yield, dividends, and a spread until maturity. The implied spread allows the calculated price to match the market price as:

$$V(t) = ContractSize * S_t * exp^{(r+s-q)*\tau(t,T,basis)}$$

S = spot price of underlying index
q = dividend yield of underlying index
T = expiry date
t = valuation date
$\tau(t, T, basis)$ = year fraction between t and T, using the defined equity futures basis
r = forward risk-free rate
s = forward implied spread

4.6.10 Futures_Equity Single Stock

Instrument Description

Equity futures are derivative financial instruments. A futures contract is an agreement to buy or sell the underlying asset at a given future date for a given price. Futures contracts are normally exchange traded. Features of the contract (specifications) are standardized and available on the exchange website. Single stock futures may be cash or physically settled.

Valuation Formula

Cash-settled single stock futures use the Futures_Equity Index methodology.

4.6.11 Futures_Bond

Instrument Description

Bond futures are financial contracts that allow the contract holder to buy or sell a specified amount of bonds at a predetermined price on a future date. These contracts are standardized and traded on organized exchanges such as CME, ICE and EUREX. At expiry, settlement is made either:

- by physically delivering bonds (physical settlement); or
- in cash (cash settlement)

depending on the terms of the contract.

With physical settlement, the futures seller (short position) has the option to deliver any of the bonds in the basket. These bonds have varying prices due to their maturity and stated coupon. To address this, an adjustment for each bond known as the *conversion factor* is calculated and utilized to make all deliverable bonds approximately equal in price. Standard pricing models assume the seller's choice will be the cheapest to deliver (CTD) bond.

With cash settlement, e.g., Australian (AUD) and Korean (KRW), futures are settled in cash against a standardized (notional) bond which is defined in the contract specifications.

Conversion factor

The conversion factor is used to equalize all deliverable bonds. It represents the estimated clean price at which 1 unit of par value of the bond would trade on the defined *delivery day* if it had a yield to maturity equal to the notional coupon (given in the contract specifications). Calculation simplifying assumptions differ slightly, depending on the exchange, but the foundation remains the same.

Valuation Formula

Physical settlement

The price of the physically-settled futures contract equals the present value (NPV) of the CTD-Bond cashflows, scaled by the conversion factor and discounted using the relevant yield curve plus a spread. The implied spread allows the NPV to match:

$$V(t) = Quoted futures price * Quantity * Contract Size$$

Cash settlement

Cash settlement is more straightforward as there is no physical delivery (or CTD). These bond futures also contain an underlying basket of bonds, but it is only used to determine settlement value. The settlement yield is computed as the average yield to maturity of the bonds in the published basket.

The price of the cash-settled futures equals the present value of the notional bond's cashflows, discounted using the relevant yield curve plus a spread. The implied credit spread allows the NPV to match:

$$V(t) = Quantity * Contract Size * \{\frac{c}{f} * (1 - V^{fm}) / \frac{y}{f} + V^{fm}\}$$

c = coupon
m = maturity term
f = notional payment frequency (e.g., 2 for semi-annual)

$y = (1 - QuotedFuturesPrice/100)$

$V = (1 + \frac{y}{f})^{-1}$ = discount factor

4.6.12 Futures_Money Market

Instrument Description

Money market futures are derivative financial instruments. A futures contract is an agreement to buy or sell the underlying asset at a given future date for a given price. Futures contracts are normally exchange traded. Features of the contract (specifications) are standardized and available on the exchange website. Futures on money market indices also known as Short Term Interest Rate (STIR) futures are cash-settled.

Valuation Formula

The market value of money market futures is calculated as:

$$V_m = MarketPrice * Quantity * ContractMultiplier$$

The market value V_m is equated to the calculated value V_c using a credit spread such that:

$$V_m = V_c = 100 * (1 - ForwardRate - CreditSpread) * Quantity * ContractMultiplier$$

The $ForwardRate$ is the annualized rate for the term of the futures contract, determined from the forward curve.

4.6.13 Forward_FX

Instrument Description

An FX Forward is an over the counter (OTC) instrument that locks in the price (fixed FX strike rate) at which a counterparty can buy or sell a currency on a future (expiry) date. Pricing does not include any upfront payment. The value may be positive or negative depending on whether the fixed strike FX rate at expiry is above or below the estimated forward FX rate.

Valuation Formula

The value of the FX Forward is based on covered interest rate parity and is calculated as:

$$V(t) = N * DF^d(t,T) * (S * \frac{DF^f(t,T)}{DF^d(t,T)} - K)$$

N =number of options = nominal amount of the FX forward
K = FX strike
S = FX spot rate
T = expiry date
t = valuation date
$DF^d(t,T)$ = discount factor in currency domestic (base)
$DF^f(t,T)$ = discount factor in currency foreign (quote)

4.6.14 Swap_Interest Rate

Instrument Description

An interest rate swap is a financial instrument through which two parties exchange cashflows based on interest rates. It consists of a paid and a received leg, where either of the legs can reference a fixed rate or floating rate. The most common interest rate swap will be a fixed-for-floating-rate swap. The floating rate is determined from a published interest rate such as LIBOR, SONIA, SOFR, ESTR etc.

Valuation Formula

$$\text{Swap Value}_t = \text{Value Received Leg}_t - \text{Value Paid Leg}_t$$

A fixed leg is priced like the Bond_Fixed Rate and a floating leg is priced like the Bond_Vanilla Floater (=Floating Rate Note) with the following differences:

1. Scheduled principal redemption as with bond pricing is considered for amortizing swaps; otherwise, final exchange principal or 0 for no principal exchange.
2. Callability and putability of the underlying legs is not considered.
3. Constant credit spread or credit curve as with bond pricing is not considered for swap valuation.

4.6.15 Swap_Inflation Linked

Instrument Description

An inflation linked swap is a financial instrument through which two parties exchange cashflows where at least one leg is based on inflation rates. It consists of a paid and a received leg, where either of the legs can reference a fixed rate or floating rate. The most common inflation rate swap will be a fixed-for-floating-rate swap where the floating rate is determined from a general price index rate such as CPI or RPI.

Valuation Formula

$$SwapValue_t = ValueReceivedLeg_t - ValuePaidLeg_t$$

A fixed leg is priced like the Bond_Fixed Rate and a floating leg is priced like the Bond_Inflation Linked with the following differences:

1. Scheduled principal redemption as with bond pricing is considered for amortizing swaps; otherwise, final exchange principal or 0 for no principal exchange.
2. Callability and putability of the underlying legs is not considered.
3. Constant credit spread or credit curve as with bond pricing is not considered for swap valuation.

4.6.16 Swap_Limited Inflation (LPI)

Instrument Description

A Limited Price Index (LPI) swap is a type of inflation linked swap i.e. at least one of the cashflow sets (legs) exchanged is based on inflation rates. The inflation payouts have a structure that is linked to inflation rates that are capped and floored at specific levels e.g. LPI (0,3) is based on RPI with a floor of 0% and cap of 3%.

An LPI swap can be considered as a strip of forward-starting and one-year caps and floors on the RPI. There is a degree of standardization in terms of boundaries e.g., (0,3), (0,5), (3,5) and maturities e.g., 5, 10, 15, 20, 25 and 30 years. Infinity caps or floors can also feature.

Valuation Formula

One approach for LPI swaps that has been adopted by the market is to price the payoffs from the series of caps and floors as European-style options. This can be done by using a variation on the Black model use for valuing interest rate caps and floors, where we model the index increase at the option maturity as a random variable.

Zero-Coupon LPI swap

For a zero-coupon LPI swap with a maturity of T:

Floating (LPI) Leg = $Max(Min(\frac{I_T}{I_0}, (1+C)^T), (1+F)^T)$

Fixed Leg = $(1+K)^T$

I_t = inflation index for observation date t
C = annual cap in % usually 3, 5 or ∞
F = annual floor in % usually -∞, 0, or 3
K = fixed leg rate (strike)

Period-on-period LPI swap

For a periodic LPI swap with defined interest dates $t_0 < t_1 < t_2 < ... < t_M$
Floating (LPI) Leg = $\prod_{t=1}^{T}(1 + LPI_t)$
Fixed Leg = $(1 + K)^T$

Unlike the zero-coupon LPI structure, the period-on-period LPI swap cannot be valued using a static portfolio inflation swap, caps, and floors. To value this swap, one needs an inflation term structure. And then the swap can be valued by simulation across the term structure of RPI.

LPI term structure can either be determined from market quotes of LPI swaps or using caps and floors priced using an analytical or other method given historical realized volatility.
An important aspect of the bootstrapping is that inflation rates can be negative, pointing to a normal distribution as opposed to the lognormal distribution used for equities. To model the calls and puts, we use the Bachelier formula that is the normal derivation of the lognormal Black-Scholes formula.

Call Price = $e^{-rt}(F - K)N(d_1) + \sigma\sqrt{T}n(d_1)$
Put Price = $e^{-rt}(K - F)N(-d_1) + \sigma\sqrt{T}n(d_1)$

$$d_1 = \frac{F - K}{\sigma\sqrt{T}}$$

F = forward inflation rate (one-year, n years forward)
S = fixed rate (strike)
T = maturity (one year)
r = risk free rate (one-year forward)

N = cumulative standard normal distribution (cdf)

n = standard normal distribution (pdf)

Using put-call parity, LPI forward rates are derived.

4.6.17 Swap_CDS Single Name

Instrument Description

A credit default swap is a financial instrument which is used to protect the buyer from an adverse credit event e.g. default by the underlying entity. It has the following property: the counter party of the credit default swap pays $(1 - RR) * nominal \quad amount$ at time of default (TD). RR is the recovery rate. For this protection, a fee s (credit spread) is paid, usually on a quarterly basis.

Valuation Formula

Required:

- Yield Curve: tenors with corresponding zero yield rates, frequency and basis
- CDS Curve: tenors with corresponding CDS spreads, frequency, basis and recovery rate

The CDS curve and the Yield Curve are used to calculate the quoted CDS rate, the hazard rates, and the survival probabilities for the CDS valuation.

$$CDSValue = s * (\sum_{j=1}^{n} \tau(T_{i-1}, T_i, basis) * DF(0, T_j) * SP(T_j) + \frac{1}{T_j - T_{j-1}} \int_{T_{j-1}}^{T_j} (t - T_{j-1}) * DF(0,t) * f(t)dt) - (1 - RR) \int_{T_0}^{T} * DF(0,t) * f(t)dt$$

s = cds spread
$SP(t) = e^{\int_0^t h(s)ds}$ = survival probability at time t (probability, that a credit event occurs after time t)
$f(t)$ = density of default
RR = recovery rate
DF = risk-free discount factor
N = Notional
$\tau(T_{i-1}, T_i, basis)$ = year fraction of the coupon period according to the day count convention specified by the coupon basis.

4.6.18 Swap_CDS Index

Instrument Description

A credit default swap index (CDS Index) is a credit derivative, which is used to hedge credit risk on a basket of credit entities. In contrast to a single name CDS, which is an OTC credit derivative, the CDS Index is completely standardized credit security and therefore more liquid. CDS indices are quoted at a constant credit spread in basis points, which represents the fraction of the protected notional that would be paid yearly to protect the index against a credit event.

Valuation Formula

Required:

- Yield Curve: tenors with corresponding zero yield rates, frequency and basis

CDS Index Valuation Formula (with accrual)

The fair value of a payer CDS Index is:

$$CDSIndexValue = \sum_{i=1}^{N} DF(t, T_i) * RiskyCashflow(i) * (quote - rate) + AccruedInterest$$

$AccruedInterest = -rate * accruedfactor * N$
$DF(t, T_i)$ = discount factor from t to the coupon date T_i
$quote$ = CDS index market spread
$rate$ = coupon rate of CDS index
N = Notional

CDS Index Valuation Cashflows

$$riskycashflow(i) = N * \tau(T_{i-1}, T_i) * (SP(T_{i-1}) - \frac{1}{2} * (SP(T_{i-1}) - SP(T_i))$$

$SP(t)$ = survival probability at time t
$\tau(T_{i-1}, T_i, basis)$ = year fraction of the coupon period according to the day count convention specified by the coupon basis.

CDS Index Valuation from a Price

Given Clean Price P of a CDS Index, the NPV is calculated as
$NPV = w * (N * (1 - P) + A)$
where $w = 1$ if the premium is paid and $w = -1$ if the premium is received
N is the notional amount of the CDS Index
A is the accrued premium during the current coupon period

From the NPV, the implied spread is derived using optimization.

4.6.19 Swap_Total Return

Instrument Description

A total return swap is a bilateral financial contract in which one counterparty pays out the total return from the underlying asset; all intermediate cashflows (dividends, interest, etc.) plus the capital appreciation or depreciation, and in return, receives a regular fixed or floating rate cashflow.

Valuation Formula

$$TotalReturnValue(t) = ValuePerformanceLeg(t) + CapGains(t) - ValuePaymentLeg(t)$$

$CapGains$ = Appreciation or depreciation of the total return leg i.e., $PerformanceLeg$. The yield curve of the $PerformanceLeg$ is used to project the future price of the underlying asset.
For $ValuePerformanceLeg$, $ValuePaymentLeg$: see Valuation Formulas for instrument types of underlying legs (Bond_Fixed Rate, Bond_Vanilla Floater (=Floating Rate Note), Bond_Inflation Linked).

NOTE:

- redemption schedules are not considered
- callability and putability are not considered
- credit spread (constant credit spread or credit curve) is not considered within the general swap valuation
- $PaymentLeg$ can be priced using the following instrument types: Bond_Fixed Rate, Bond_Vanilla Floater (=Floating Rate Note), Bond_Inflation Linked
- $PerformanceLeg$ can be priced using the same instruments as the $PaymentLeg$ as well as Equity.
- If the swap **resets**, then, Swap Reset Dates = coupon dates of the $PaymentLeg$. Reset dates are adjusted using the business day convention and holiday calendar of the $PaymentLeg$. If the swap resets, the notional of the $PaymentLeg$ grows or shrinks with the $PerformanceLeg$ price.

In period i the notional of the $PaymentLeg$ is:
$N * S_{i-1}/S_0$

N = notional
S_{i-1} = $PerformanceLeg$ Price in period $i-1$
S_0 = $PerformanceLeg$ Price on start date

4.6.20 Option_Equity

Instrument Description

The owner of the option has the right (not the obligation) to buy (call) or sell (put) shares of the underlying equity at the option expiry date for a given price (strike price). The underlying equity has a spot market price and may pay discrete dividends at certain dates or may be subject to a dividend yield.

Valuation Formula

The value of a European vanilla equity option, paying continuous dividends, is calculated using the Black Scholes Formula:

Call value = $C(S,t) = e^{-r(T-t)}[F * N(d_1) - K * N(d_2)]$

Put value = $P(S,t) = e^{-r(T-t)}[K * N(-d_2) - F * N(-d_1)]$

where

$$F = Se^{(r-q)(T-t)}$$

and

$$d_1 = \frac{1}{\sigma\sqrt{T-t}}[ln(\frac{S}{K}) + (r - q + \frac{1}{2}\sigma^2)(T-t)]$$

$$d_2 = \frac{1}{\sigma\sqrt{T-t}}[ln(\frac{S}{K}) + (r - q - \frac{1}{2}\sigma^2)(T-t)] = d_1 - \sigma\sqrt{T-t}$$

S = spot price of the underlying equity

T = expiry date

t = valuation date

K = strike price

N = cumulative standard normal distribution

If the option has Bermudan or American exercise rights, the value of the option is calculated using a partial differential equation (PDE) approach.

Options on equity indices are also priced using this method.

4.6.21 Option_Equity Future

Instrument Description

The owner of the option has the right (not the obligation) to buy (call) or sell (put) shares of the underlying equity futures at the option expiry date for a given price (strike price).

Valuation Formula

The Black 76 model is a variant of the Black Scholes model that can be used to price European options on futures where the spot price is replaced by a discounted futures price:

Call value = $C(S,t) = e^{-r(T-t)}[F * N(d_1) – K * N(d_2)]$

Put value = $P(S,t) = e^{-r(T-t)}[K * N(-d_2) – F * N(-d_1)]$

where

$$d_1 = \frac{1}{\sigma\sqrt{T-t}}[ln(\frac{F}{K}) + (r + \frac{1}{2}\sigma^2)(T-t)]$$

$$d_2 = d_1 - \sigma\sqrt{T-t}$$

F = futures price

T = expiry date

t = valuation date

K = strike price

N = cumulative standard normal distribution

If the option has Bermudan or American exercise rights, the value of the option is calculated using a partial differential equation (PDE) approach. Equity Future Options can only be calculated using a flat volatility assumption.

Options on equity index futures are also priced using this method.

4.6.22 Option_FX

Instrument Description

FX represents the foreign exchange (FX) rate between 2 currencies which may be defined as domestic vs foreign currency, primary vs secondary currency or quoting vs base currency. The spot FX rate is the price for one unit of the foreign currency, expressed in units of domestic currency. Using a risk-free approach, the term structure of the FX rate depends on the interest rate curves in the foreign and domestic currencies.

A vanilla FX option is a financial instrument with the following properties: The owner of the option has the right (not the obligation) to buy (call) or sell (put) 1 unit of the foreign currency at the option expiry date for a certain amount (the strike FX rate) of domestic currency.

Valuation Formula

The value of a European vanilla FX option can be calculated using the Black Scholes Formula:

Call value = $C(S,t) = S * N(d_1) - Ke^{-r(T-t)}N(d_2)$

Put value = $P(S,t) = Ke^{-r(T-t)}N(-d_2) - S * N(-d_1)$

where

$$d_1 = \frac{1}{\sigma\sqrt{T-t}}[ln(\frac{S}{K}) + (r + \frac{1}{2}\sigma^2)(T-t)]$$

$$d_2 = d1 - \sigma\sqrt{T-t}$$

S = FX spot price

T = expiry date

t = valuation date

K = FX strike price

N = cumulative standard normal distribution

If the option has Bermudan or American exercise rights, the value of the option can be calculated using a partial differential equation (PDE) approach.

4.6.23 Option_Swap (Swaption)

Instrument Description

A vanilla swaption is a financial instrument with the following properties: The owner of the vanilla swaption has the right (not the obligation) to become the fixed rate payer (payer swaption) or to become the floating rate payer (receiver swaption) of a vanilla interest rate swap with a constant remaining lifetime at the swaption's expiry date.

Valuation Formula

Valuation of a vanilla swaption can be performed under a *lognormal* Black76 or *normal* Bachelier model. The default model used is the *normal* Bachelier model as we source normal volatilities from our market data provider. Valuation can be performed using a single or multi curve approach (if additional forward curve is provided). Settlement may be evaluated as physical or cash.

Models Used

Black 76 (Caps/Swaptions)

$$dF_t = \sigma_L F_t dW_t$$

$F_0 = f$ = today's forward swap/caplet rate
σ_L = Lognormal volatility

Bachelier (Caps/Swaptions)

$$dF_t = \sigma_N dW_t$$

$F_0 = f$ = today's forward swap/caplet rate
σ_N = Normal or absolute volatility

Black76 Vanilla Swaption Valuation Formula

The formula for the fair price of a payer swaption with strike *K* and cash settlement *C* in the Black76 model is:

$$C = a * e^{-r(T)} * (F * N(d_1) – K * N(d_2))$$

The formula for the fair price of a receiver swaption with strike *K* and cash settlement *P* in the Black76 model is:

$$P = a * e^{-r(T)} * (K * N(-d_2) - F * N(-d_1))$$

where

$$d_1 = \frac{1}{\sigma\sqrt{T}}[ln(\frac{F}{K}) + (\frac{1}{2}\sigma^2)T]$$

$$d_2 = d_1 - \sigma\sqrt{T}$$

and

$$a = \frac{1 - (1 + \frac{F}{m})^{-tm}}{F}$$

Bachelier Vanilla Swaption Valuation Formula

$$C = a * e^{-rt}[(F - K)N(d_1) + \sigma\sqrt{T}n(d_1]$$

$$P = a * e^{-rt}[(K - F)N(-d_1) + \sigma\sqrt{T}n(d_1]$$

where

$$d_1 = \frac{F - K}{\sigma\sqrt{T}}$$

C = call price

P = put price

T = time to expiry

N = cumulative standard normal distribution (cdf)

n = standard normal distribution (pdf)

4.6.24 Property_REIT

Instrument Description

Real Estate Investment Trust (REIT) are tradeable instruments where investment proceeds purchase shares of participation in income-generating property assets, primarily rent from commercial properties. REITs either invest directly to take title/ownership or invest in the loans/mortgages. The purpose of creating the legal framework for a REIT structure was to enable a wider group of (mostly small) investors to gain access to the alternative asset class of commercial real estate.

Publicly traded REITs can be bought and sold as equities, and private REITs issue operating units that are essentially the same.

Valuation Formula

REITs are valued using the Equity methodology.

4.6.25 Property_Direct (CRE)

Instrument Description

Direct property investments represent ownership and management of physical property i.e., buildings or land with the intention of generating returns. The investor makes gains on their investment through rental income, profits generated from associated activities and capital appreciation.

Valuation Formula

Direct properties are valued using the Bond_Fixed Rate and Bond_Inflation Linked methodologies, but lease description and rental income information is used in place of bond description and coupon information. Direct property cashflows are also derived differently from those of regular bonds
The following additional information is required:

1. Rent_review_frequency and Next_rent_review_date
2. Deal IRR

Direct Property Cashflow

Net cashflows are determined as:
$RentalIncome + OtherPropertyIncome – PropertyExpenses$

1. Rental income can be reviewed/adjusted using a fixed or floating rate e.g. inflation index

For inflation adjustment, Rental_Income =
$RentalAmount_t * (IndexValue_t/IndexValue_0)$

Otherwise, a fixed rate is used such that Rental_Income =
$RentalAmount_t * (1 + FixedRateAdjustment)$

2. Other_Property_Income =

$PropertyValue_0 * [(1 + AddnlIncomeYield)^t - [(1 + IRR – AddnlIncomeYield)^{t-1}]$

where

$AddnlIncomeYield = IRR – CurrentRentalYield$

and

$$CurrentRentalYield = RentalIncome/PropertyValue$$

3. Property_Expenses =

$$PropertyValue_t * ExpenseRate$$

Expenses are a balancing item so that the discounted present value of the cashflows is equal to the property value on valuation date.

Want to find out more? You can find the most up-to-date product documentation on Moody's Information Web (https://information.moodysanalytics.com)

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Documentation

Information Web: https://information.moodysanalytics.com

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